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A CASE STUDY OF ESTUARINE SEDIMENTATION IN MISSION BAY-SAN DIEGO BAY, CALIFORNIA

Charles E. Rambo, et al

Marine Advisers, Incorporated

Prepared for:

Department of the Interior

February 1969

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A CASE STUDY OF ESTUARINE SEDIMENTATION IN MISSION BAY - SAN DIEGO BAY, CALIFORNIA

Prepared for

U. S. Department of the Interior
Federal Water Pollution Control Administration

Contract No. 14-12-425

By

Charles E. Rambo
William C. Speidel

MARINE ADVISERS, INC. LA JOLLA, CALIFORNIA
a subsidiary of THE BENDIX CORPORATION

February 1969

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Frontispiece

Aerial view of Mission Bay, Point Loma and San Diego Bay looking south, 1968. (City of San Diego)

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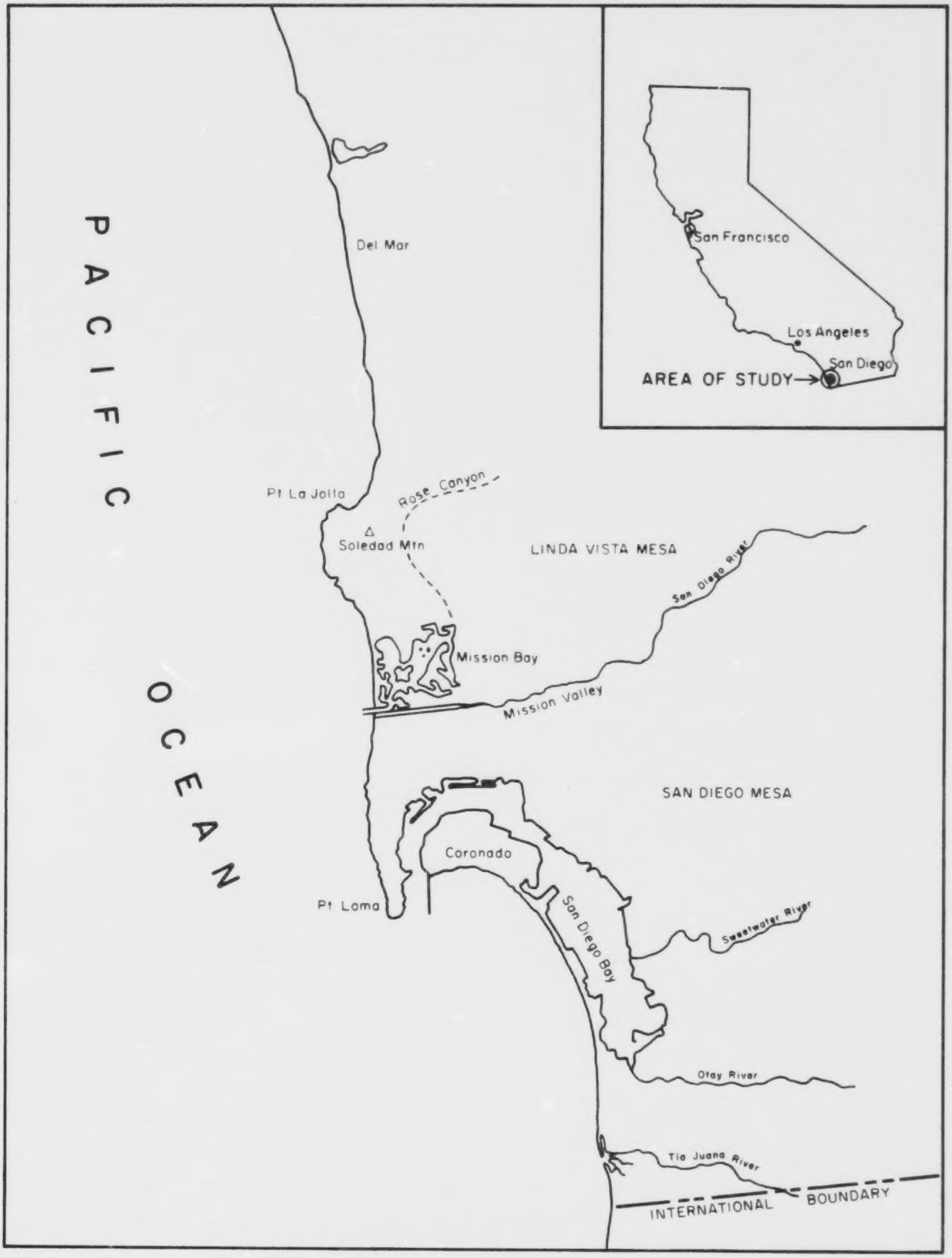
INTRODUCTION

The objective of this study has been to describe and to document a situation in which new and increased use of an estuarine system has resulted from control of sedimentation. The system we have chosen to examine includes the San Diego River, Mission Bay, which was once called False Bay, and San Diego Bay shown in Figure 1. The specific location of the present entrance channel to Mission Bay is lat 32°45'30" N, long 117°15'00" W.

No effort has been made to determine how this system compares with other such systems in which beneficial uses have been realized as the result of sedimentation control efforts. The physical description of the system and the environmental parameters have been documented through as much of the history of the system as possible. Against this background, the transformation of this estuarine environment is traced through its development at the hands of the community. Much of the data pertaining to the present study is fragmented because of the variety of agencies, both private and public, which have been involved in development of river and bays. Comparative studies between this system and others may not be feasible on a quantitative basis. However, in future unified studies, the nature of the data available on this system may serve, along with that of other representative systems, as a frame of reference for more quantitative environmental analyses.

Figure 1

Location Map


San Francisco
Los Angeles
San Diego
AREA OF STUDY
PACIFIC
OCEAN
Del Mar
Pt La Jolla
Rose Canyon
Soledad Mtn
LINDA VISTA MESA
San Diego River
Mission Bay
Mission Valley
SAN DIEGO MESA
Coronado
Pt Loma
San Diego Bay
Sweetwater River
Otay River
Tia Juana River
INTERNATIONAL BOUNDARY

A-323

Two aspects of the system and its recent history merit some comment with regard to the man-made changes in the environment and the intent or desire result which lead to these changes. The system has evolved through four stages:

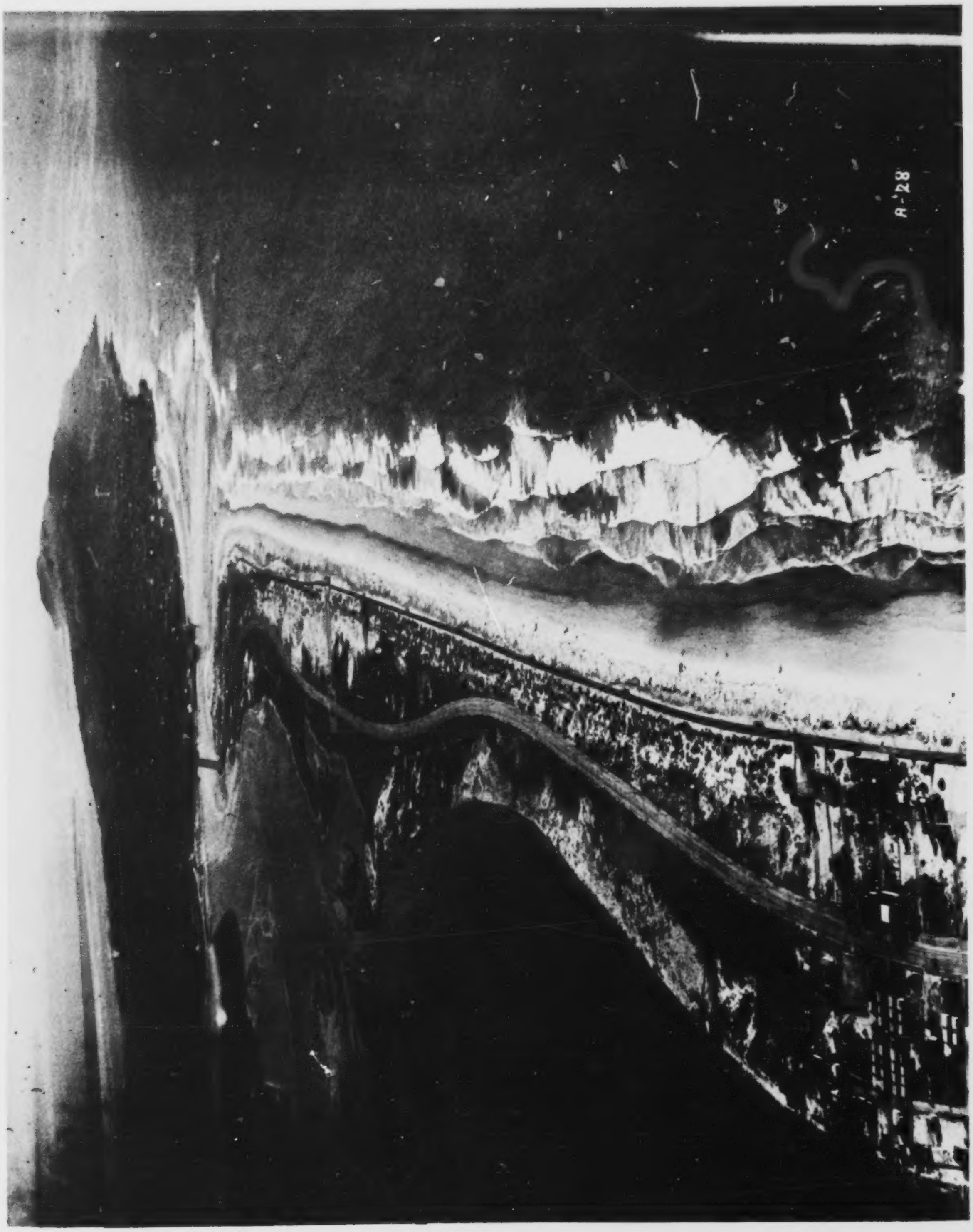
1. River emptying directly into the sea.
2. River and two separate estuarine environments.
3. River and Mission Bay system.
4. River isolated.

When the San Diego River was permanently directed into the Mission Bay portion of the delta in 1877, San Diego Bay became part of an independent estuarine system fed by rivers between San Diego and the international boundary.

The characteristics of the San Diego River system are sufficiently complex to warrant qualifying the application of the terms estuary and estuarine system. Emery et al. (1957) noted that an estuary is a body of water separated from the ocean by land masses that were originally shaped by nonmarine processes. A lagoon is an environment similar to the estuary but is generally considered to be separated from the ocean by land masses of marine origin. Mission Bay is separated from the ocean by both forms of land. The Point Loma highland and Crown Point terrace partially separated the Bay from the open ocean. In later stages of development, the marine feature along the present western boundary of the Bay became the barrier. The barrier approached complete closure as shown in Figure 2.

Figure 2

A 1917 view looking south of Mission Beach, the entrance channel to Mission Bay, Point Loma and San Diego Bay. (Historical Collection, Title Insurance and Trust Company, San Diego, California.


A-28

The study has been developed in three phases. These phases are presented in separate sections of the report. The first consideration was the recent development (recorded history) of the estuarine system. This history of the river and two bays is used as the context for illustrating the economic factors and recreational aspects of land use associated with the system.

Sedimentation in the estuarine system is examined in the second section. It is necessary to refer to the physiography of the area in recent geologic history (pre-recorded history) in order to describe the natural sedimentary cycle of the river basin. This section naturally overlaps the recent developments in the prior section,particularly on the subject of flood control.

The final section deals with Mission Bay as an example of the natural end product in the control of sedimentation. The considerations faced during planning of the final development of the Bay are examined.

Mission Bay is an outstanding example of the result of community planning in an estuarine environment. This development was undertaken because it could be shown that it was technically feasible, that it had support from the community, and that the expected benefits to the community could be realized in a reasonable time. San Diego Harbor is an example of a small port which was once threatened by estuarine sedimentation. The Harbor is now a major port because this sedimentation was controlled tnrough efforts of City, State and Federal governments.

Collecting the information pertinent to the history of San Diego and the development of the estuarine system would not have been possible without the cooperation of several persons. The generous assistance received from the following persons and their organizations is gratefully acknowledged:

Philip H. Benton
Benton Engineering, Inc.
San Diego, California

Leonard D. Booth, Jr.
Reference Library
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San Diego, California

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City of San Diego, California

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San Diego, California

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San Marino, California

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San Diego, California

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Board of Port Commissioners
San Diego, California

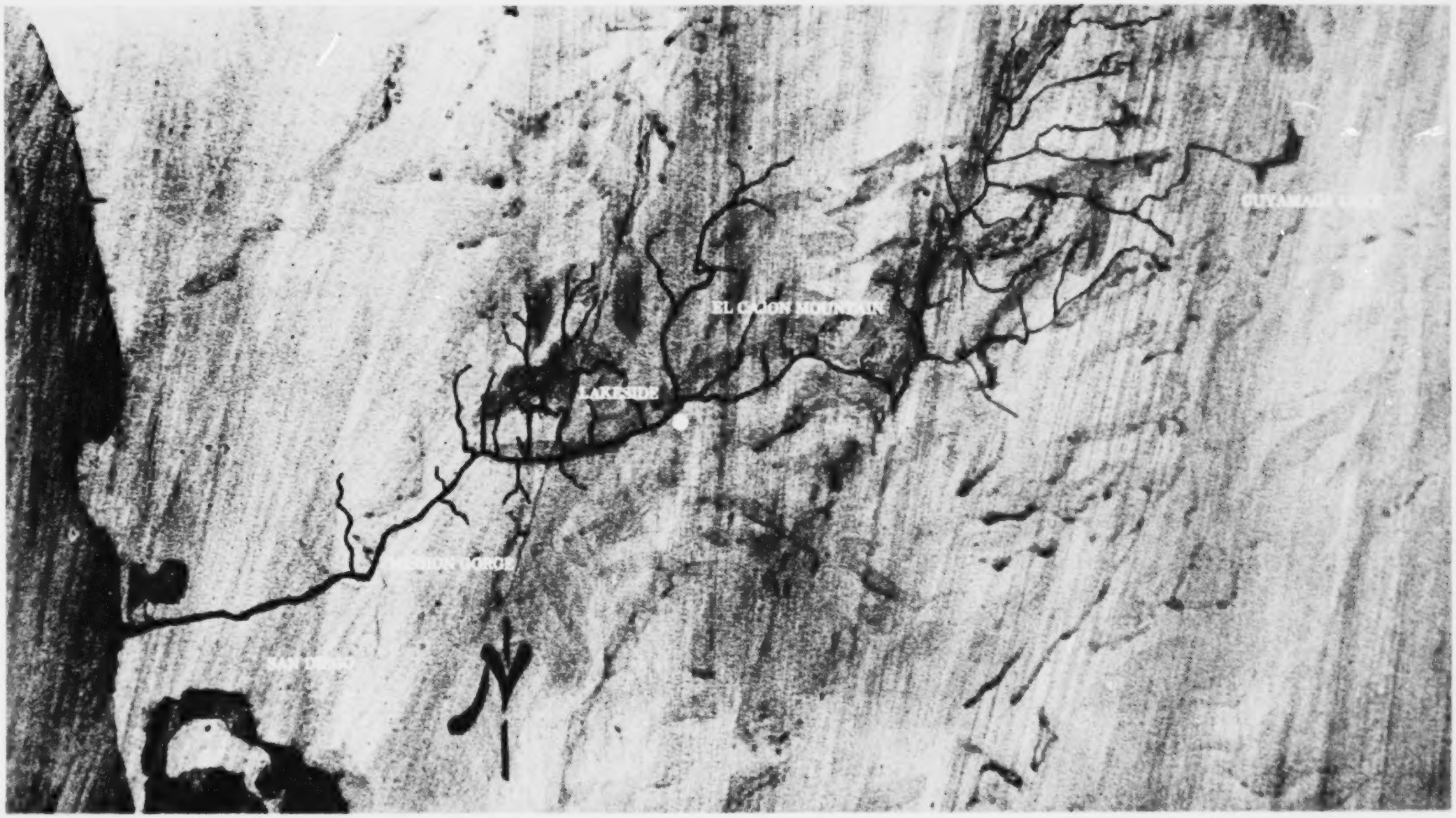
RECENT DEVELOPMENT OF THE ESTUARINE SYSTEM

Introduction

The control of sedimentation in the San Diego River Basin has developed since the middle of the 19th century. Various diversion efforts in the upper basin (above the delta), however, cannot be included in "control efforts" in the context of the present study. The steps leading to the present controlled system, whether for local objectives in the basin, or for management of the estuarine system, were clearly not part of a unified plan. In the beginning, the needs of the time were met with little regard for long range development. Water requirements forced inhabitants in the basin to utilize as much of the rainfall as practical. This began to diminish the effective sediment potential of the drainage basin. Diversion of the river channel on the delta was the first major step in controlling the estuarine sedimentation. This stemmed from a direct threat to an existing port. The most recent major change in the system had its basis in the concept that control would lead to potential development in the community. There is a subtle difference in the motivation behind the public involvement in these last two developments in the system. San Diego Bay was saved and further development proceeded as the economy demanded it. In the case of Mission Bay, the control effort was clearly an investment in the future of the community (Frontispiece).

Figure 3

Map of the San Diego River and its tributaries.
(From Pourade, 1966)


CUYAMACA LAKE
EL CAJON MOUNTAIN
LAKESIDE
MISSION GORGE
SAN DIEGO
N

The emphasis of the community's involvement during the recent history will be described in the paragraphs which follow.

Course of the San Diego River

The configuration of the San Diego River watershed is shown in Figure 3. The mouth of the river has meandered periodically across the surface of the delta. This has been documented in recent history and can logically be assumed to have occurred in recent geologic history. The fact that the river course meandered on the delta was not of much significance to the present study prior to the time the delta overlapped the higher ground of the Point Loma area. Once the delta closed the gap between San Diego Bay and False Bay, it is possible that the river course might have continued to flow permanently into one or the other of the bays. In order to avoid possible confusion regarding place names, a short anecdote will illustrate how False Bay originally came by its appellation.

History records the first discovery of Mission Bay by a party of Spanish sailors who became lost on the way back to their ship from an exploring expedition. Thinking this smaller bay was San Diego Bay and figuring that the ship had left without them, they began what they expected to be a long journey to La Paz, some 800 miles away. Within the hour, however, they came upon their ship lying peacefully at anchor in the real San Diego Bay. The scene of their error they named False Bay, and so it remained until 1915 when the U. S. Board of Geographic Names officially accepted Mission Bay as the proper name (Union Title Insurance Company, 1960).

The first references to the course of the river are found in Costanso's narrative (1910) and on a map drawn by Vicente Vila, Captain of a supply ship with the Portola expedition of 1769 - 1770. Vila's map in Figure 5 shows the river debouching into San Diego Bay. An earlier chart from the Vizcaino expedition of 1602 (Figure 4) does not show the river, and the first known explorer, Juan Rodriguez Cabrillo who came to this area in 1542 left neither journal nor chart.

San Diego Bay was charted in 1782 by Don Juan Pantoja y Arriaza, pilot on a Spanish supply vessel. Pantoja's map is reproduced in Figure 6, and shows the San Diego River emptying into San Diego Bay.

Subsequent references to the course of the river are sporadic. Lieutenant George Derby of the Corps of Topographical Engineers reported on this area in 1853 and noted that the San Diego River had emptied into San Diego Bay prior to 1811. In his report, Lieutenant Derby indicated that the river did not cut a channel into San Diego Bay until 1825. Juan Bandini's history (Pourade, 1961) concurs with the 1825 shift, and Duhaut-Cilly reported in 1827 that the river was flowing into False Bay (Carter, 1929).

Pourade (1961) notes that in 1842 M. Duflot de Mofras, an attache with the French Legation in Mexico, wrote the following observations on a trip to San Diego:

> "At San Diego, the fort and the presidio are uninhabited: On one side of the fort under the crumbling walls a few pieces of bronze cannon lie partially buried; at the pueblo,

Figure 4

First known chart of San Diego Bay drawn in 1603 from soundings and notes obtained by the Sebastian Vizcaino expedition. (From Pourade, 1960)

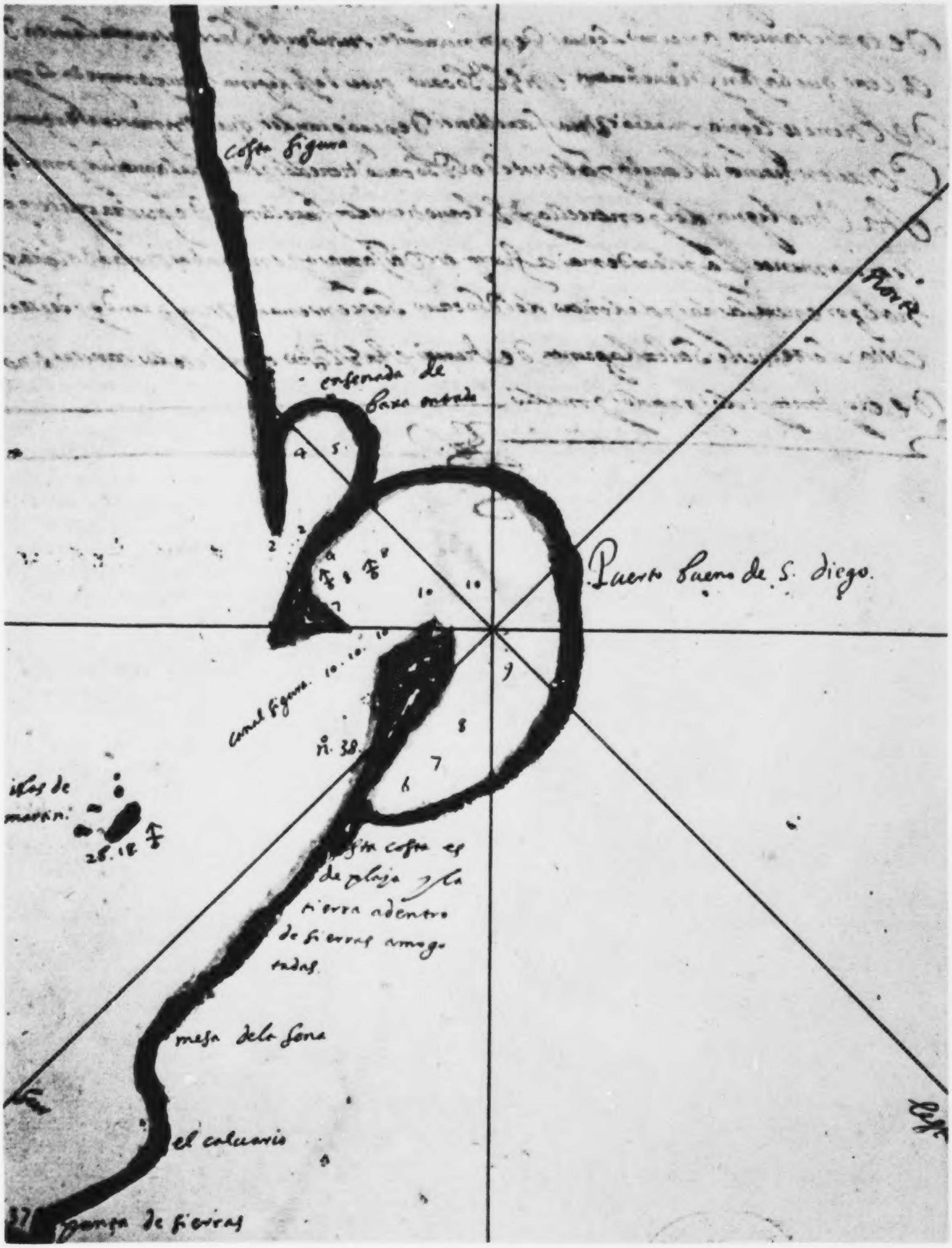

Costa sigura
ensenada de
baxa entrada
Norte
4
5
2
3
4
8
8
7
10
10
Puerto bueno de S. diego.
10
10.10.
canal sigura
9
8
ñ. 38.
7
6
islas de
marin.
28. 18
esta costa es
de playa y la
tierra adentro
de sierras amogo
tadas.
mesa dela sona
Sur
Lest
el calvario
37
punta de sierras

Figure 5

A chart of San Diego Bay drawn in 1770 by Vicente Vila is the first map showing the San Diego River. (From Pourade, 1960)

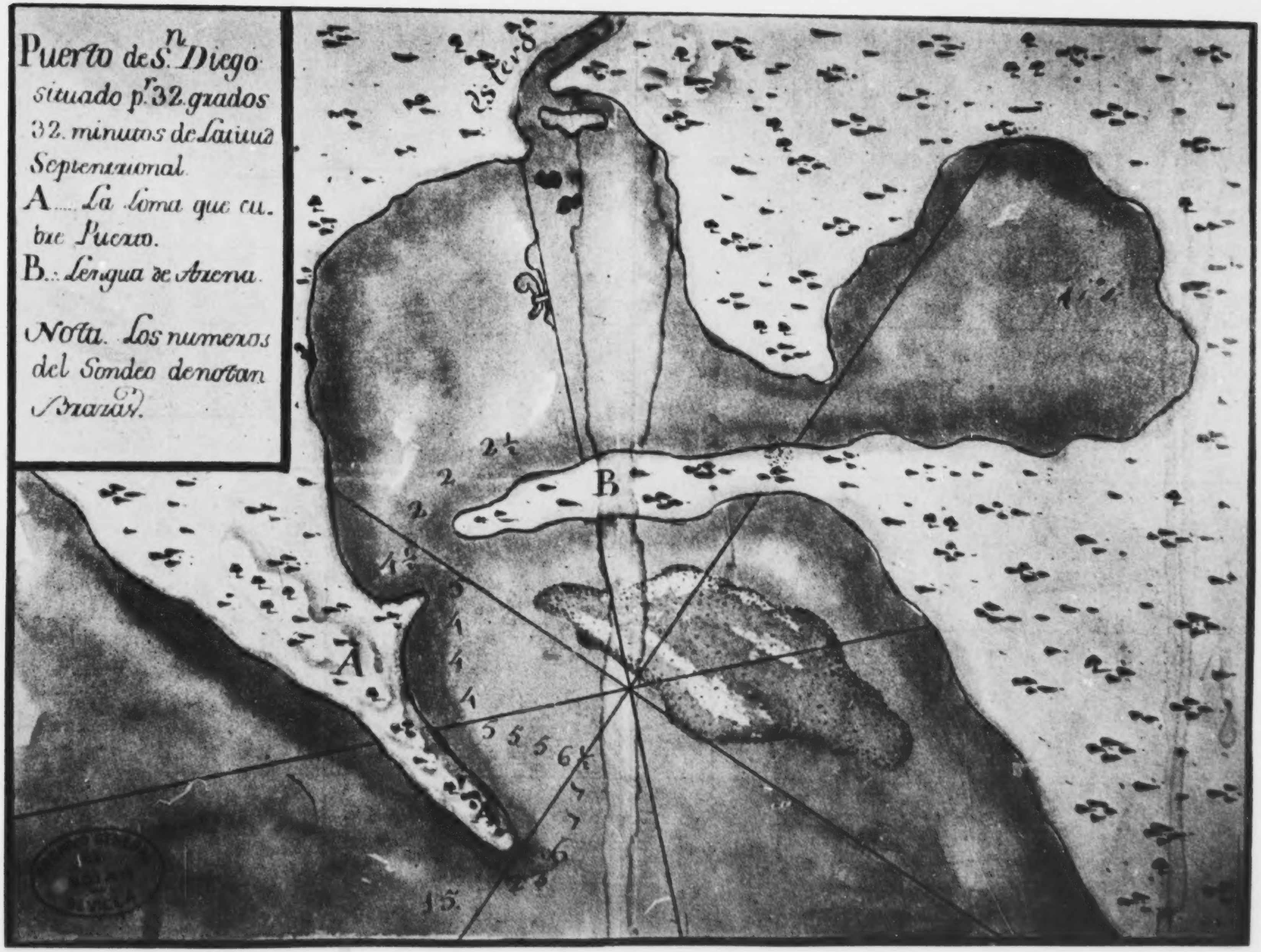
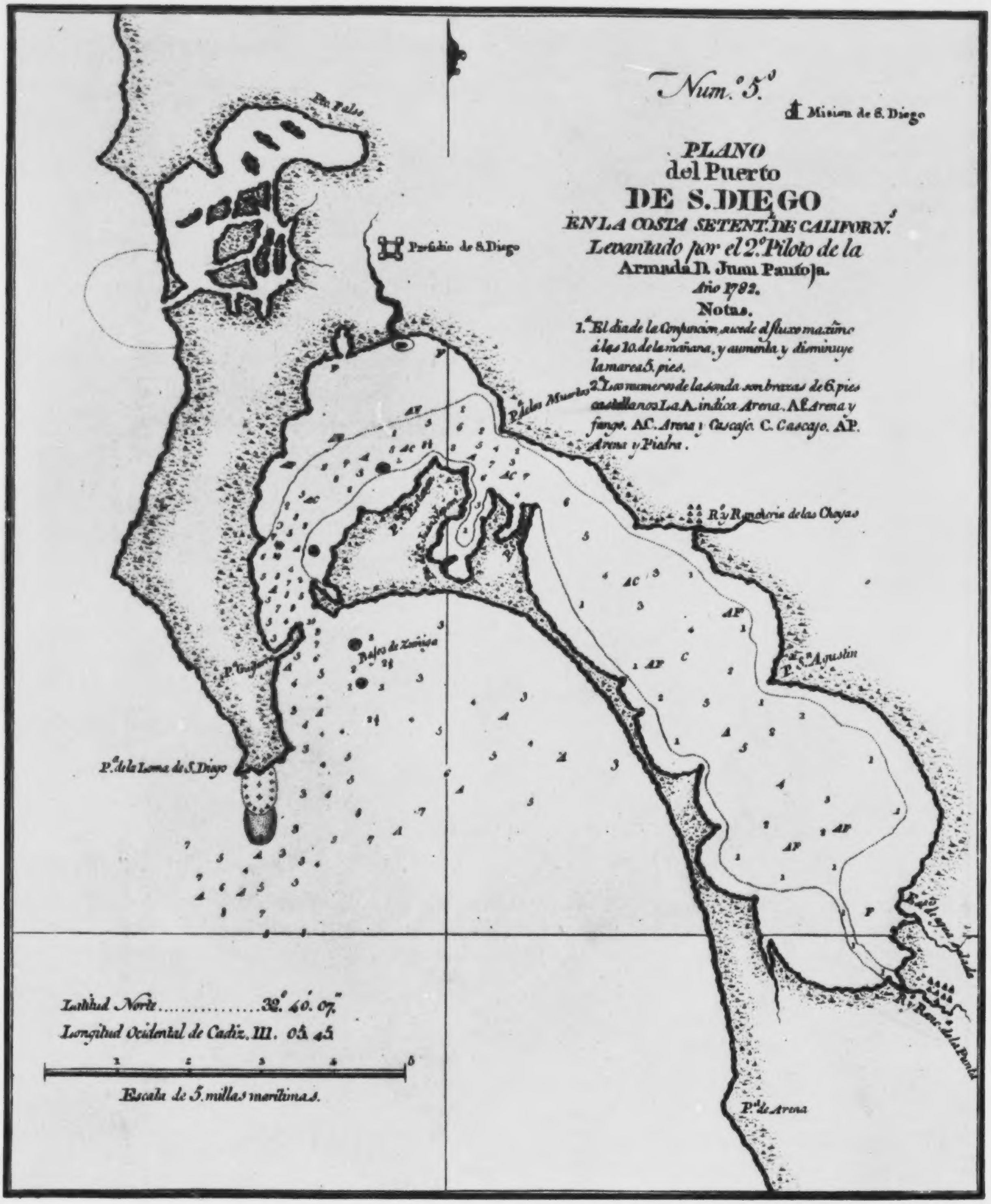

Puerto de Sn. Diego
situado pr. 32. grados
32. minutos de Latitud
Septentrional.
A..... La Loma que cu-
bre Puerto.
B... Lengua de Arena.
Nota. Los numeros
del Sondeo denotan
brazas.
A
B
2½
2
2
4½
5
4
4
4
5
5
5
6
7
7
6
15

Figure 6

In 1782, Don Juan Pantoja made this chart showing San Diego Bay, False Bay and the mouth of the San Diego River. (Henry E. Huntington Library, San Marino, California)



Num.º 5.º

PLANO
del Puerto
DE S. DIEGO
EN LA COSTA SETENT. DE CALIFORN.ˢ
Levantado por el 2.º Piloto de la
Armada D. Juan Pantoja.
Año 1782.

Notas.

1.ª El dia de la Conjuncion, sucede el fluxo maximo á las 10. de la mañana, y aumenta y disminuye la marea 5. pies.

2.ª Los numeros de la sonda son brazas de 6. pies castellanos. La A. indica Arena. AF. Arena y fango. AC. Arena y Cascajo. C. Cascajo. AP. Arena y Piedra.

Latitud Norte .... 32.° 40.′ 07.″
Longitud Ocidental de Cadiz. III. 05. 45.

Escala de 5. millas maritimas.

Mision de S. Diego
Pta. Falso
Presidio de S. Diego
P. de los Muertos
R.ª y Rancheria de las Choyas
P. S.ⁿ Agustin
Bajos de Zuñiga
P. Guijarros
P.ª de la Loma de S. Diego
R.ª de agua salada
R.ª y Ranc. de la Punta
P.ᵗᵃ de Arena
AF
AC
AP
1
2
3
4
5

> a few soldiers in charge of an officer reside. Only ships of 400 tons drawing less than 20 feet of water are allowed to enter the port of San Diego. Certain areas are shallow, and some parts are so covered with sand banks that ships can easily run aground on the silt that the tiny San Diego River brings down from the mountains in the rainy season.
>
> Within the last few years the river, through the negligence of the inhabitants, has returned to its former channel and now empties into the waters of San Diego Harbor. The fort (Fort Guijarros) and neighboring buildings are deserted and in ruins; fragments of six or eight bronze cannons may be seen embedded in the sand."

In 1848, Lieutenant William H. Emory of the United States Army Topographical Engineers, having examined old Spanish charts and an 1843 report by a Royal Navy officer, Captain Edward Belcher, wrote this about the San Diego River:

> "Well grounded fears are entertained that the immense quantity of sand discharged by this river will materially injure, if it does not destroy the harbor of San Diego; but this evil could be arrested at a slight cost, compared with the objects to be obtained. At present San Diego is, all things considered, perhaps one of the best harbors on the coast from Callao to Puget's Sound, with a single exception, that of San Francisco. In the opinion of some intelligent navy officers, it is preferable even to this. The harbor of San Francisco has more water, but that of San Diego has a more uniform climate, better anchorage, and perfect security from winds in any direction. However, the commercial metropolis must be at San Francisco, owing to the greater extent and superiority of the country adjacent, watered by the rivers, Sacramento and San Joachim, unless indeed San Diego should be made the terminus of a railroad leading by the route of the Gila to the Del Norte, and thence to the Mississippi and the Atlantic." (Pourade, 1963)

The probability that San Diego Bay might be destroyed by sediment from San Diego River was recognized by someone with sufficient influence to do something about it. Emory also recognized the fact that the immediate countryside surrounding the Bay at San Diego might not always limit the City's importance as a port. His report generated further interest and led to the events which might be called the era of Derby's Dike.

An 1850 map of the Port of San Diego drawn by an engineer, Andrew B. Gray, shows the river debouching into San Diego Bay (Figure 7). A sketch made of the area by the artist, H. M. T. Powell, about the same time shows San Diego Bay, False Bay and the San Diego River (Figure 8).

Derby's Dike

Based on Lieutenant Emory's report, the U. S. Coast Survey had warned as early as 1851 that sediment from the San Diego River seriously endangered San Diego Bay's future as a port. Residents had been unsuccessful in diverting the flow of the river by building sand and brush obstacles.

The Congressional River and Harbor Act of 1852 authorized federal improvement of San Diego Harbor. This represented the first river and harbor work undertaken by the Topographical Engineers in California. This occurred only two years after California achieved statehood.

The Corps of Topographical Engineers dispatched Lieutenant George Horatio Derby to study the situation at San Diego. His report to Congress in 1853 stated:

> "At the time of the first establishment of the Mission of San Diego, and the 'Presidio', or the military post, this plain, and in fact the whole valley for six miles above, was covered with a dense forest of sycamore, willow and cottonwood, with an undergrowth of various kinds of shrubbery, among which the wild grape was most abundant.

Figure 7

Sketch of the Port of San Diego drawn by
Andrew Gray in 1850. (From Pourade, 1963)

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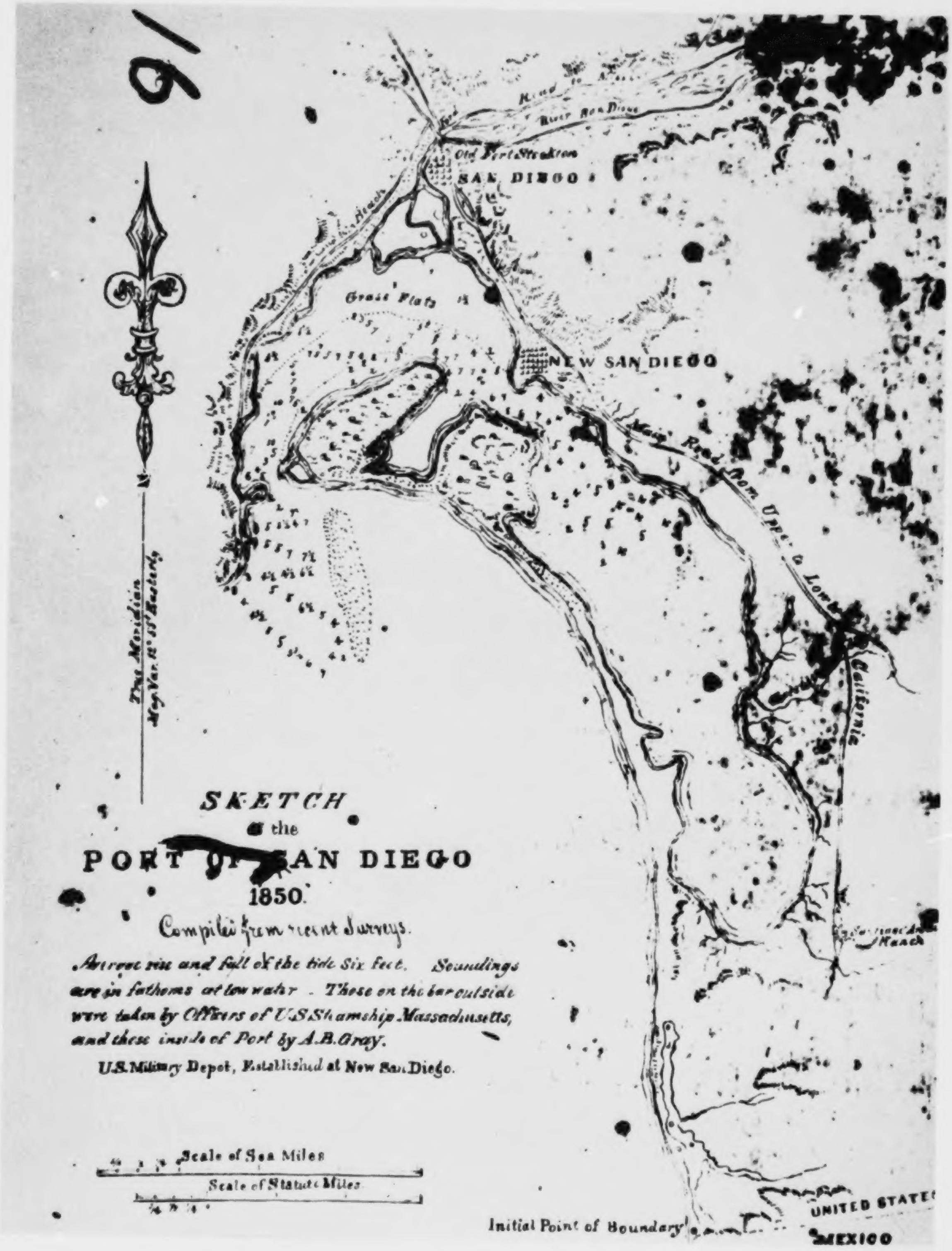

Road to
River San Diego
Old Fort Stockton
SAN DIEGO
Grass Flats
NEW SAN DIEGO
Main Road from Upper to Lower California
True Meridian
Mag. Var. 12° 25' Easterly
N
Rancho
Scale of Sea Miles
Scale of Statute Miles
Initial Point of Boundary
UNITED STATES
MEXICO

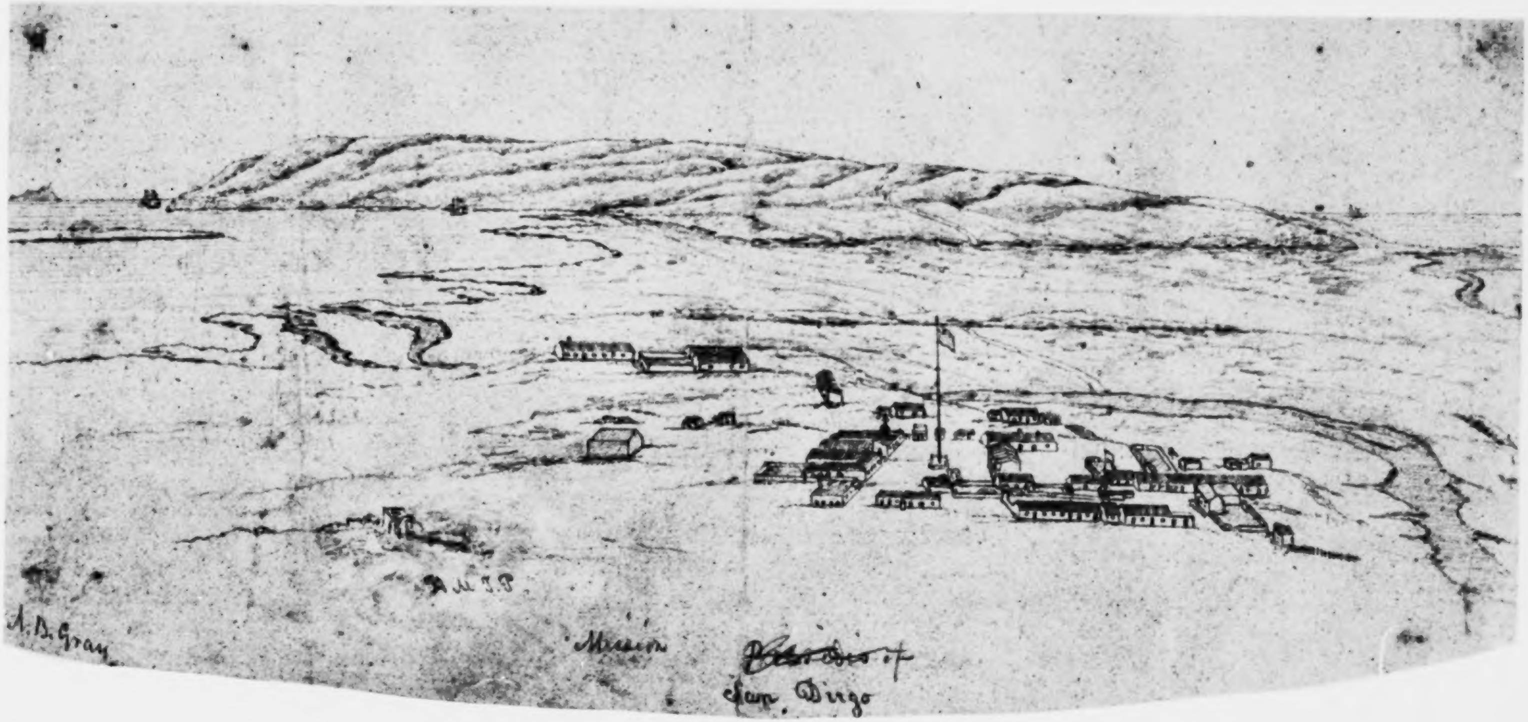
SKETCH
of the
PORT OF SAN DIEGO
1850.
Compiled from recent Surveys.

Average rise and fall of the tide Six feet. Soundings are in fathoms at low water. Those on the bar outside were taken by Officers of U.S. Steamship Massachusetts, and those inside of Port by A.B. Gray.

U.S. Military Depot, Established at New San Diego.

Figure 8

This 1851 sketch of the Presidio, San Diego Bay and Point Loma by the artist, H. M. T. Powell, also shows the San Diego River and a portion of False Bay. (Henry E. Huntington Library, San Marino, California)


A.B. Gray
A.M.I.P.
Mission
~~Presidio~~ of
San Diego

> At this time, the river ran through the most northerly part of the plain, skirting the hills . . . and emptied into False Bay. This course it continued until 1811, when, by continued deposit of sand, its bed was so much elevated that it altered its channel to the southwest, still however, emptying into False Bay, until 1825, when a great freshet occurring, it overflowed its banks, destroying many gardens and much property, and formed a new channel discharging into the harbor of San Diego. From the continued accumulation of sand, its course has somewhat fluctuated but has never been essentially altered since that period." (Pourade, 1960)

Lieutenant Derby prepared a chart of the river delta area and recommended construction of a dike. This plan is shown in Figure 9. Derby recommended a heavier type construction than ould be approved by the Board of Engineers. In 1853, Lieutenant Derby built the dike using Indian labor. The structure extended from a point near the base of Presidio Hill to the eastern end of Point Loma. A timber bulkhead was constructed to block the river channel, thus preventing further sedimentation in San Diego Bay. In Derby's report to Washington, he warned that the foundation material under the dike was too soft and would be undermined in a short time.

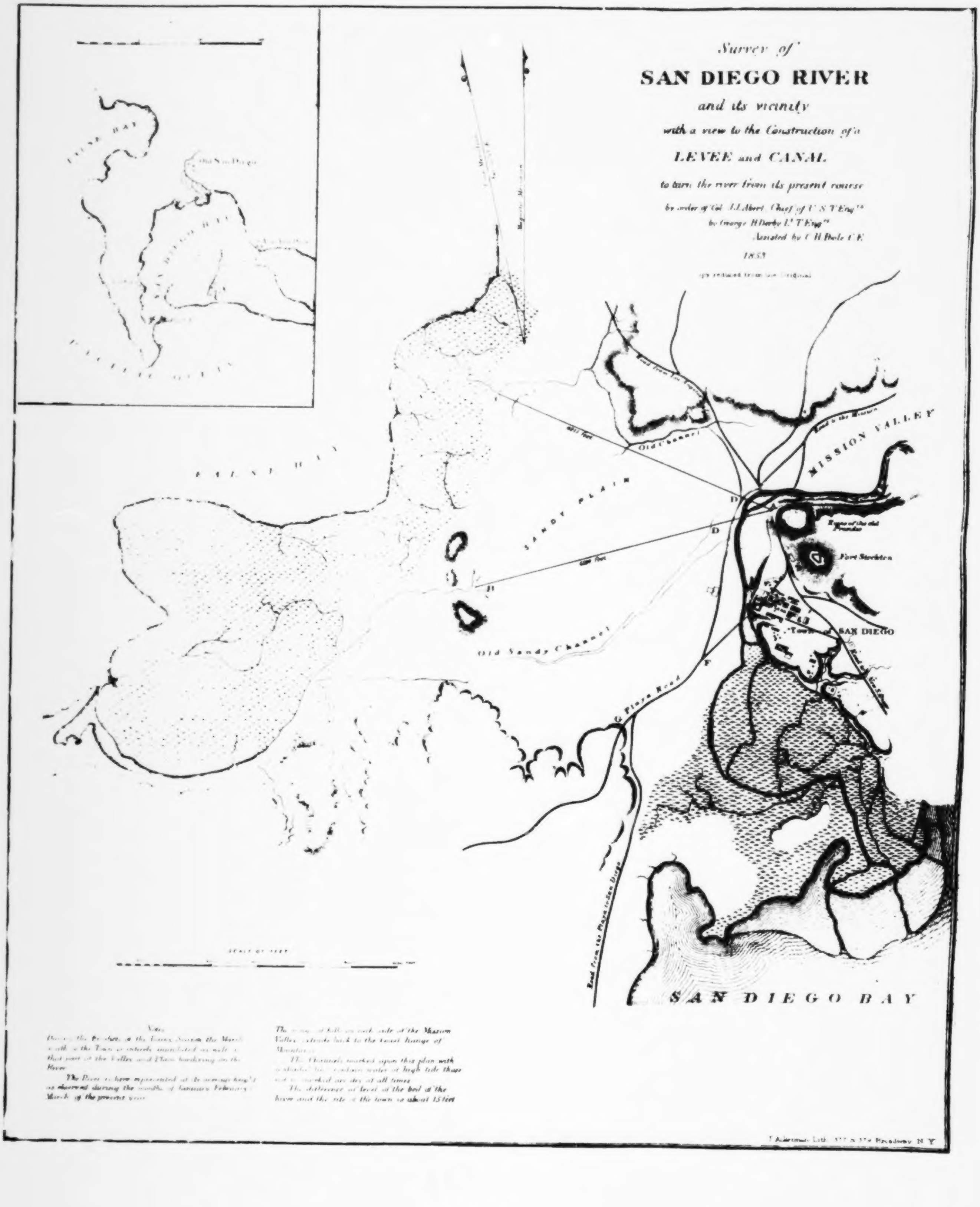
The dike did prove to be inadequate and within two years was destroyed. This original dike was constructed for $30,000.

A map of the pueblo lands of San Diego drawn in 1870 (Figure 11) shows the river emptying into San Diego Bay. The situation on the delta was essentially the same as it had been prior to the government's attempts to solve the silting problem.

Congress took up the matter again in 1875 and authorized an

Figure 9

The 1853 map of the San Diego River resulting from Lieutenant George Derby's survey. The sketch shows the proposed location of the diversion dike, which was accepted and eventually built, only to collapse two years later. (Historical Collection, Title Insurance and Trust Company, San Diego, California)



Survey of

SAN DIEGO RIVER

and its vicinity

with a view to the Construction of a

LEVEE and CANAL

to turn the river from its present course

by order of Col. J.J. Abert, Chief of U. S. T. Eng.rs
by George H. Derby L.t T. Eng.rs
Assisted by C. H. Poole C.E.

1853

(reduced from the original)

Old San Diego
False Bay
Pacific Ocean
Magnetic Meridian
Road from San Diego to the Mission
Road to the Mission
MISSION VALLEY
Old Channel
FALSE BAY
SANDY PLAIN
Ruins of the old Presidio
Fort Stockton
Town of SAN DIEGO
Old Sandy Channel
Playa Road
Road from the Playa to San Diego
SAN DIEGO BAY
B
D
D
E
F
G
SCALE OF FEET

Notes

During the freshets in the Rainy Season the Marsh south of the Town is entirely inundated as well as that part of the Valley and Plain bordering on the River.

The River is here represented at its average height as observed during the months of January February March of the present year.

The range of hills on each side of the Mission Valley extends back to the Coast Range of Mountains.

The Channels marked upon this plan with a shaded line contain water at high tide those not so marked are dry at all times.

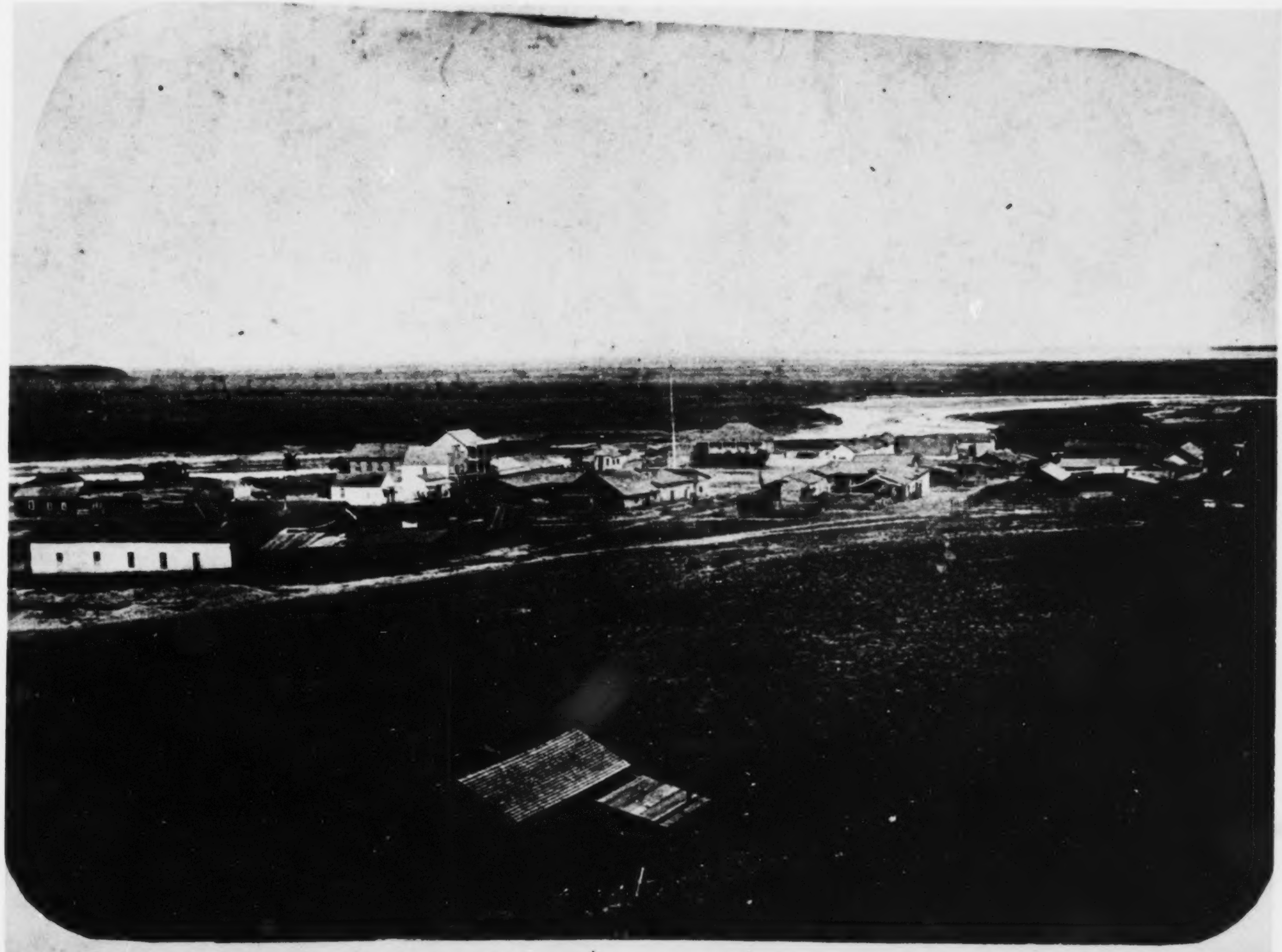
The difference of level at the bed of the River and the site of the town is about 15 feet

J. Ackerman Lith. 379 & 381 Broadway N.Y.

Figure 10

San Diego's Old Town in 1869 is shown on the bank of the San Diego River. False Bay and the northeast end of Point Loma can be seen in the background. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

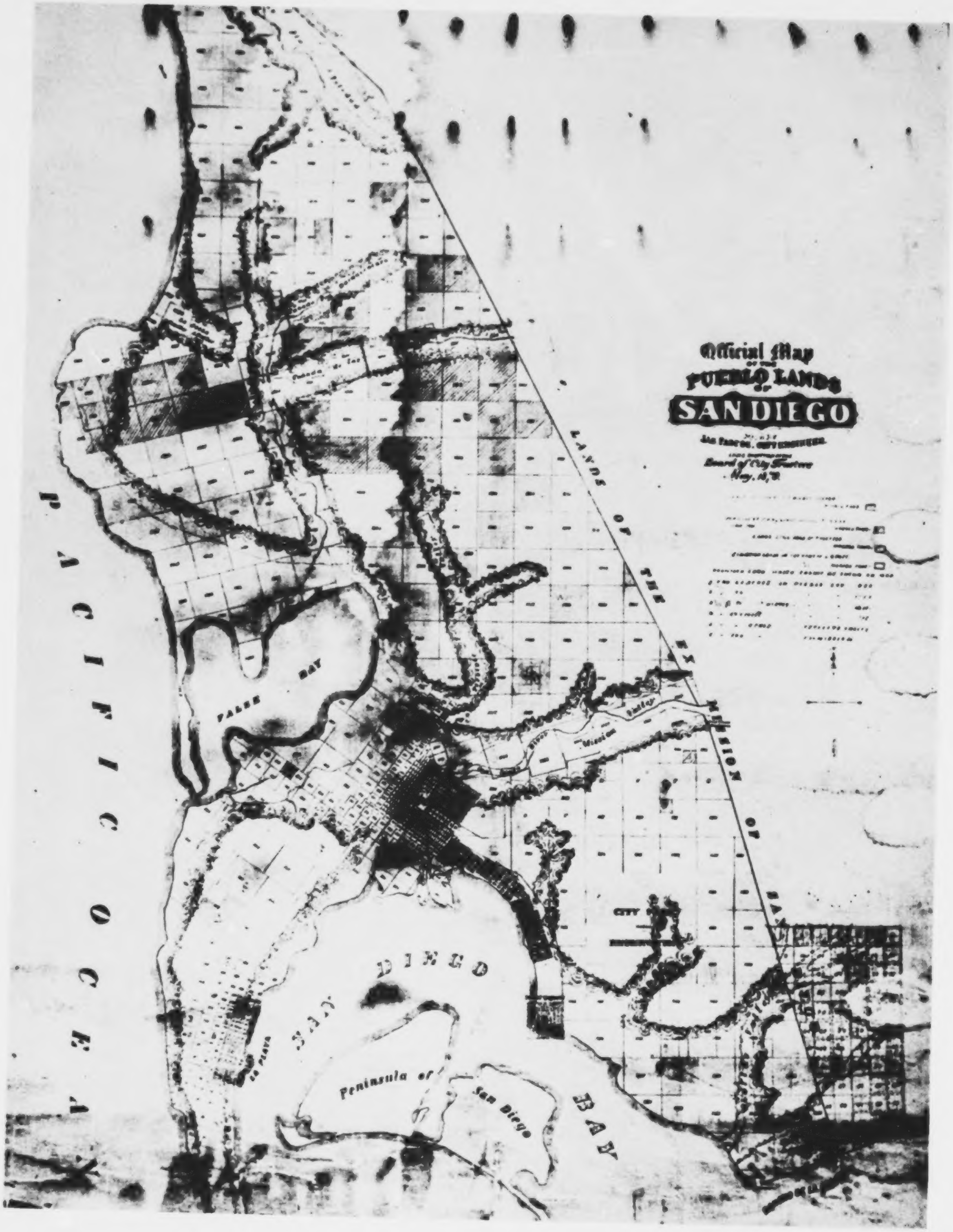
036<



San Diego Old Town
taken from Rudolph Schiller January 1869.

Figure 11

Map of the pueblo lands of San Diego in 1870. The San Diego River bed is depicted on the final leg of its course into San Diego Bay seven years before its final diversion. (From Pourade, 1964)


Official Map
of the
PUEBLO LANDS
of
SAN DIEGO
Jas Pascoe, City Engineer
Board of City Trustees
PACIFIC OCEAN
FALSE BAY
SAN DIEGO BAY
Peninsula of San Diego
La Playa
Mission Valley
CITY
LANDS OF THE EX MISSION OF SAN

expenditure of $80, 000 for a second attempt to divert the course of the river from San Diego's harbor. As had been planned by Derby, this would assure that all sediment reaching the river mouth would be deposited in False Bay. A contract was awarded by the Corps of Engineers to Captain George A. Johnson and Mr. Howard Schuyler. Their group undertook construction of a levee between the base of Presidio Hill and Point Loma. They explosively excavated 4, 000 to 5, 000 cubic yards of soil for the structure which was 41 feet wide at the base, 23 feet wide at the top, and 7735 feet long. It rested on a foundation of boulders and cobbles 3 feet deep (Pourade, 1964). San Diego Bay was thus saved from further sediment deposition and the sediment load of the San Diego River was directed into False Bay when this structure was completed in 1877.

Photographs taken in 1898 show remnants of Derby's Dike as the structure had come to be called (Figure 12).

C40<

Figure 12

An 1898 panorama looking from north to west (right to left) from atop Presidio Hill. Mission Bay, Mount Soledad and the San Diego River bed are readily recognized.

Derby's dike can be seen extending from the base of the hill by the bridge abutment across the valley floor and terminating at the northeast corner of Point Loma near the left edge of the photograph. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

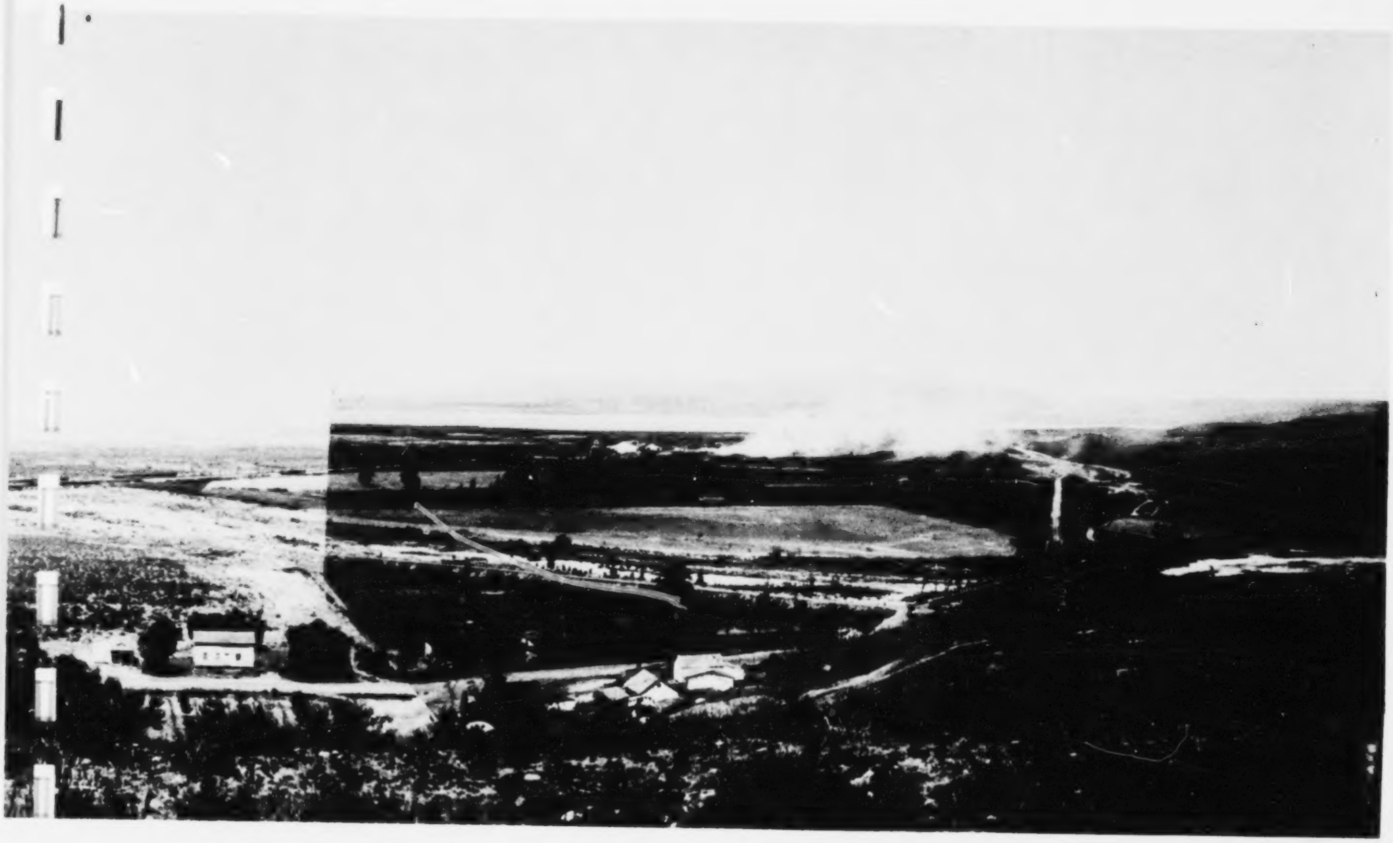


Figure 13

An 1876 photograph of Old Town shows the San Diego River twisting toward San Diego Bay. Completion of the final diversion dike a year later left this bed dry forever. This view is taken from Presidio Hill. Point Loma is in the background. (Historical Collection, Title Insurance and Trust Company, San Diego California)

044<

Figure 14

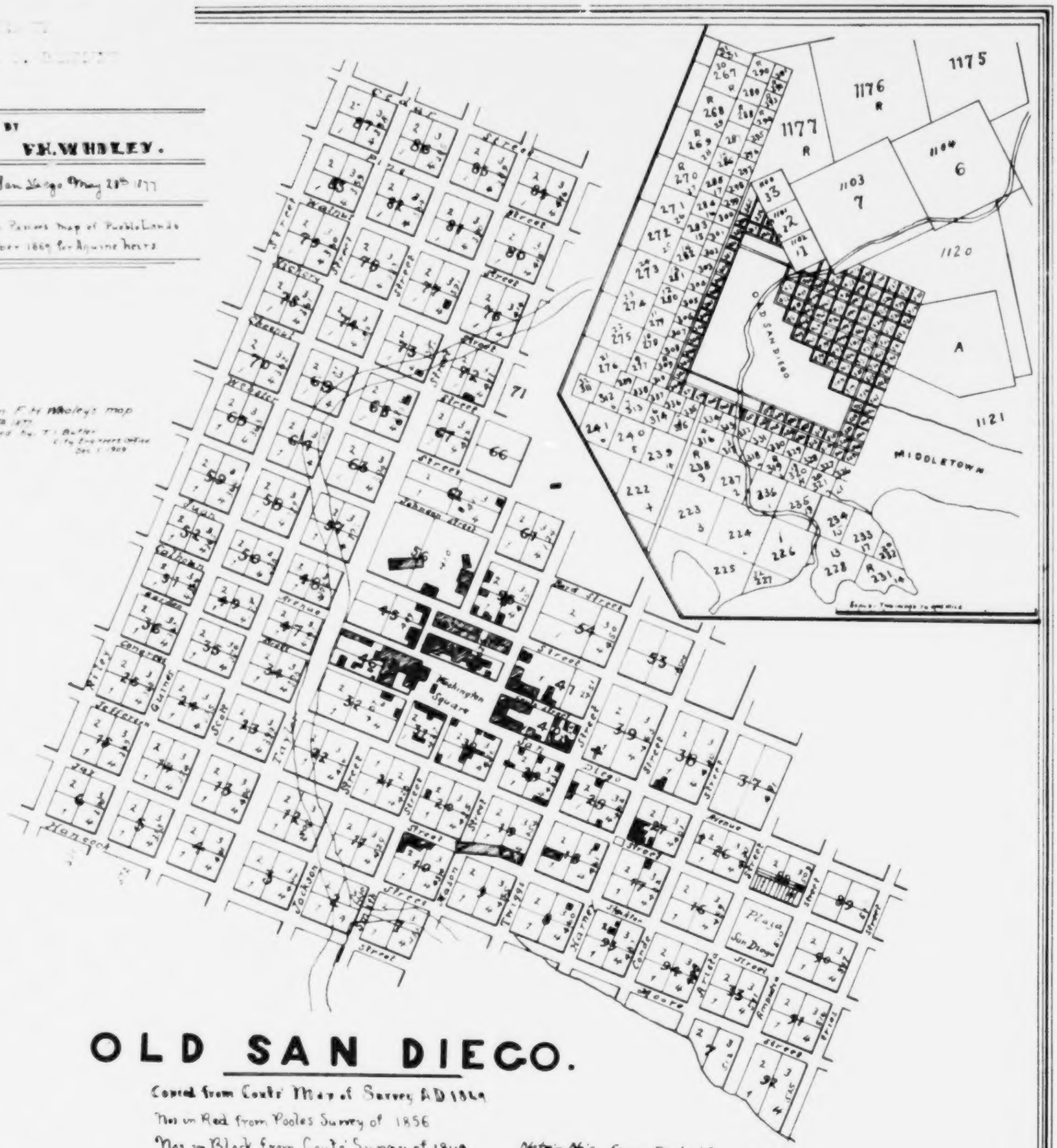
This 1877 map of Old San Diego shows the outline of the San Diego River bed. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

Copied by

F.H. WHALEY.

Old San Diego May 28th 1877

Taken from Pascoes map of Pueblo Lands
December 1869 for Aguirre heirs


Washington Square
Plaza
San Diego
Old San Diego
Middletown
1175
1176
1177
1103
1104
1120
1121
A
Jefferson
Congress
Calhoun
Hancock
Jackson
Taylor
Scott
Mason
Twiggs
Harney
Conde
Moore
Arista
Johnson Street
Street

Traced from F.H. Whaley's map
of May 28th 1877
Copied by T. I. Butler
City Engineers Office
Dec. 1 1909

OLD SAN DIEGO.

Copied from Couts' Map of Survey A.D. 1849

Nos in Red from Pooles Survey of 1856

Nos in Black from Couts' Survey of 1849

SCALE

Note:- No's from Pooles' Survey of 1856
Changed to Orange on this map for
blue print purposes.

Development of Mission Bay

A few people in the local community may have had thoughts about the future role False Bay might play in the identity of metropolitan San Diego when they succeeded in having its name changed to Mission Bay. This was initiated in 1914 and confirmed a year later. In a few years, progress was being made toward making Mission Bay an integral part of the community. J. D. Spreckels began laying a streetcar line to Mission Beach in 1922 to provide transportation to a resort and amusement center which he planned to create. His $4,000,000 amusement park opened in 1925. Spreckels was the first one to make any physical alterations to the Bay. He dredged a small cove called Bonita Basin on the bay side of Mission Beach near the amusement park. The amusement park is still in operation and the original basin was incorporated in the present configuration of the Bay. Spreckels may be credited with initiating the chain of events which involved the public in the area and eventually led to the full development of Mission Bay Park. The original shape of Bonita Basin can be seen in Figure 15.

The California State Legislature incorporated Mission Bay into the State Park System in 1929. The economic depression following 1929 and the rising threat of a world war which finally materialized a little over a decade later combined to retard the inevitable development of Mission Bay.

The San Diego side of the river delta, secured by the levee construction of 1877, had developed to such an extent by 1941 that the possibility of flood damage to the area was a major concern to the community. The Board

Figure 15

A 1935 view of Mission Bay showing the area prior to significant development. The tide flats stand out sharply. Bonita Basin, the first undertaking by J. D. Spreckels, can be seen on the left side of the photograph. (City of San Diego)

of Engineers for Rivers and Harbors cited that developments on private, city and federal lands would be involved in the event of another major flood. Local residents were reportedly pressing hard for improvements to the existing dike. At that time, the federal government had extensive facilities which were vital to the national defense.

The Secretary of War concluded (House of Representatives Document 635, 1942) that it was in the Navy's interest to protect the San Diego Bay side of the delta from floods. The principal facilities cited in the opinion included the Navy and Marine Corps training establishments and the industrial complex directly related to national defense.

Other wartime activities related to the river delta were mentioned in House of Representatives Document 760, 1946. There were reports on the subject of beach erosion in Mission Bay by the Beach Erosion Board. Levee improvement was authorized by Act of Congress, Public Law 534, Chapter 665, in December, 1944. This construction was never undertaken. The District Engineer cited the need for improvements in Mission Bay in a letter of May 1945. The interest in improving small craft navigation in Mission Bay was noted at that time.

The first direct involvement in the development of Mission Bay by the City of San Diego came in April 1945 when the State of California granted the tidelands and submerged lands of Mission Bay to the City. The voters approved a $2,000,000 bond issue and earmarked another $1,500,000. Thus, the development was underway. Dredging operations commenced in 1946. A summary of dredging projects related to the development up to 1965 is shown in Table 1.

Federal assistance was forthcoming when the San Diego River and Mission Bay Project was authorized by Act of Congress under Public Law 525, 79th Congress, 2nd Session. The authorized project included flood control on the San Diego River and navigation on Mission Bay in accordance with plans recommended by the Chief of Engineers. This action by the Congress was the 1946 River and Harbor Act. Several factors were cited in justification of the project. It was noted in House Document 760 that justification for the flood control project depends largely on benefits to accrue from the change in land use. The benefits at that time were considered to depend on navigation development. Erosion on the coast was a problem,and it was considered that the new channel would supply the normal river sediment load directly to the coast where it might tend to reduce erosion. Mosquito control was cited as an immediate benefit. This had become a serious problem in the tidal flats on the east side of the Bay.

In this regard, the State of California became involved and was able to assume part of the costs because the project qualified under the State Flood Control Act of 1945. With the city, state and federal governments heavily committed, local attention was turned toward attracting private investment.

According to a Corps of Engineers information sheet (1965) the City of San Diego, by resolution of the City Council in January 1948, formally guaranteed and assured the Secretary of the Army that "it would undertake, perform

TABLE 1

Mission Bay Dredging Projects to July 1, 1965

Year		Cu. Yds. Dredged	Unit Price	Cost of Dredging
1946				
	Gleason Point	200,000	$0.25	$ 50,000
	Santa Barbara Cove	81,919	.20	16,384
	Ventura Point, Ventura Cove	533,316	.178	94,930
1947				
	Santa Clara Point, Juanita Basin, El Carmel Point, Carmel Cove,	933,770	.1574	179,901
	Sunset Point, Dana Basin	809,674	.1499	121,370
	Tierra del Fuego, Adjacent Channels (West), Pacific Cove, Atlantic Cove	1,164,478	.1339	155,924
1948				
	Asher Cove	845,046	.193	124,494
	De Anza Point, Adjacent Channels (East)	1,928,562	.1728	333,255
1951				
	East of Midway Drive, Cabrillo Inlet	466,019	.242	112,776
1952				
	De Anza Point & Vicinity	(1,273,890)	(.428)	(545,225)
	San Diego School District	179,706	.428	76,914
	State Park Land	89,327	.321	28,674
	City of San Diego	1,004,857		439,637
1961				
	City Share			16,819
	Area-wide Dredging Contract			4,733,441
1965				
	Remedial Dredging Rose Creek	30,000	.665	30,609
			Total	$6,515,130

From City of San Diego Engineering Department report October 1965 by J. K. Patterson.

and comply with all of the conditions required by the Acts of Congress in the acquisition and construction of the multi-purpose project for flood control and navigation of San Diego River and Mission Bay". The City committed itself to comply with the following provisions:

1. Provide, without cost to the United States, all lands and rights-of-way, including spoil disposal areas necessary for construction of the improvements.
2. Make all necessary alteration to highway bridges, utilities and side drainage structures.
3. Purchase and hold in the public interest the lands between the flood control channel and Mission Bay, west of Highway 101.
4. Prepare definite plans and construction schedules for the improvement of the bay area for park purposes, which shall be subject to approval of the Secretary of the Army.
5. Complete the improvements of the 8-foot dredging and park development within five years after completion of the Federal project.
6. Provide adequate facilities for storage, maintenance and supply of small craft.
7. Maintain and operate the entire project, except maintenance of jetties, stone revetment constructed by the United States and project depths in areas dredged by the United States.
8. Protect the carrying capacity of the floodway from future encroachments or obstructions.
9. Hold and save the United States free from damages due to the construction works.

The Bay is shown in Figure 16 before construction was started on two jetties which were built in 1948 - 1949. This was the beginning of the flood control channel shown in Figure 17. The north jetty (Figure 17) was completed

Figure 16

This 1948 photograph shows Mission Bay just before improvements were made to the entrance channel and before the floodway was built. Other dredging and shaping projects had begun. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

055

Figure 17

This 1951 photograph shows the San Diego River flood control channel. The jetty on the extreme left of the photograph will be the north side of the entrance channel when completed. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

in 1950. This formed the entrance channel to Mission Bay, shown in Figure 18. This pilot channel sanded in rapidly after dredging. It created such a serious navigational hazard for small craft that the channel was declared closed in 1951. Eight lives were lost due to drowning. During the period before the channel was closed, forty-two rescues were made, fifteen boats were capsized and thirty had to be retrieved. The Bay channel was reopened in July 1955 after more dredging. The Bay and part of the entrance channel are shown shortly after the second opening in Figure 19. This latest channel dredging opened the way for further Bay development.

Another bond issue was passed in 1956 in the amount of $5, 000, 000. This provided for dredging in the inner Bay. A beach was started along the east shoreline. The changes which were made between 1956 and the present can be seen in Figure 20. These most recent developments involved the original Bonita Basin area where work had been begun by Spreckels and the large delta portion on the southeast side of the bay.

Private Investments

The population growth in southern California, general economic growth, and a rapidly expanding tourist economy combined to provide the public involvement beyond the tax dollar which had been hoped for in the Master Plan of 1956. The rate of growth of the San Diego County population was reduced slightly during the depression years, but the trend set between 1900 and 1930 was resumed when World War II began. The record of the County population is shown in Figure 21, including a projection into the next century. Projections of beach attendence are shown in Figure 21a.

Figure 18

View looking southeasterly toward Mission Bay and San Diego Bay in 1951. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

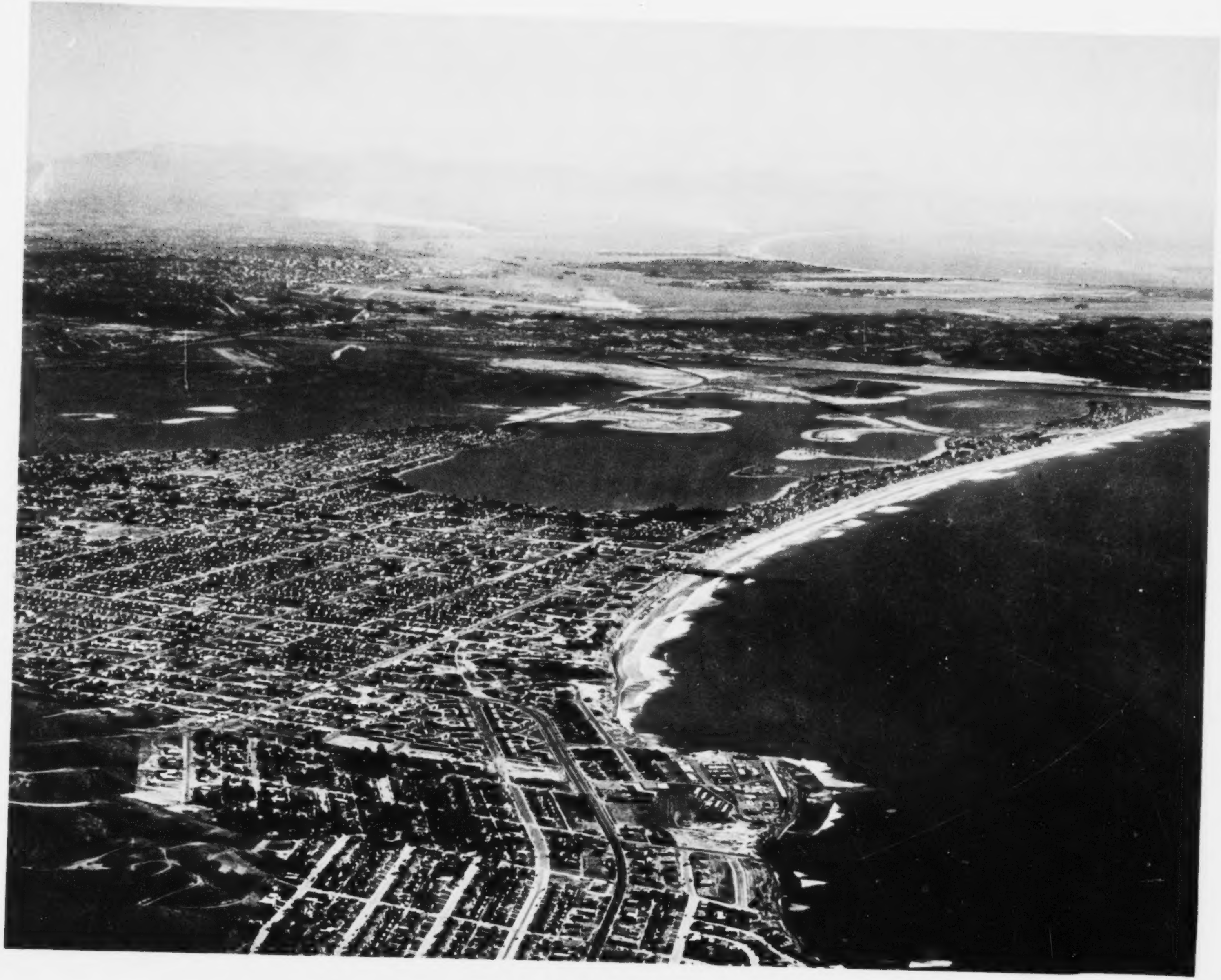


Figure 19

This 1956 aerial view shows the tremendous strides in the development of Mission Bay. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

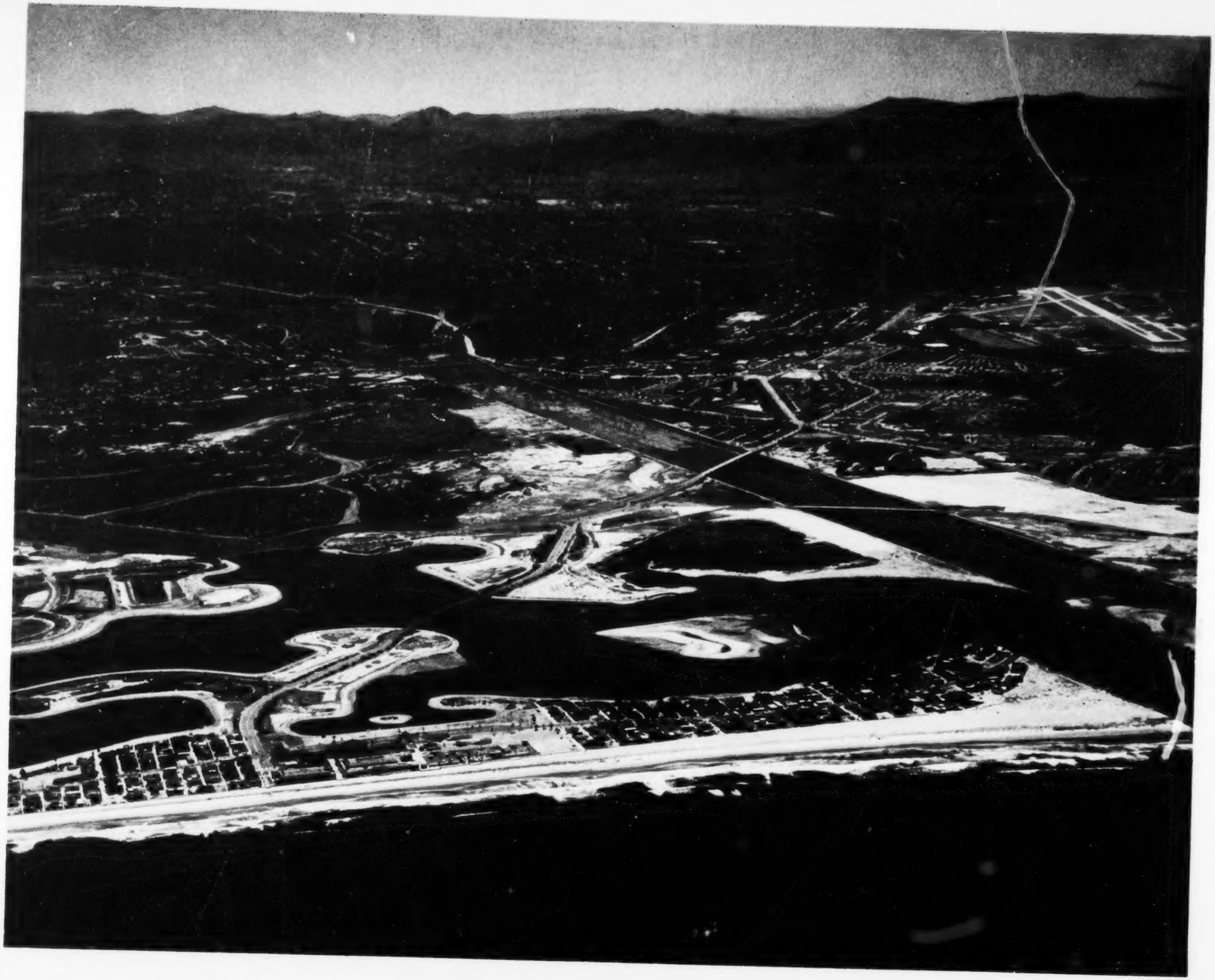
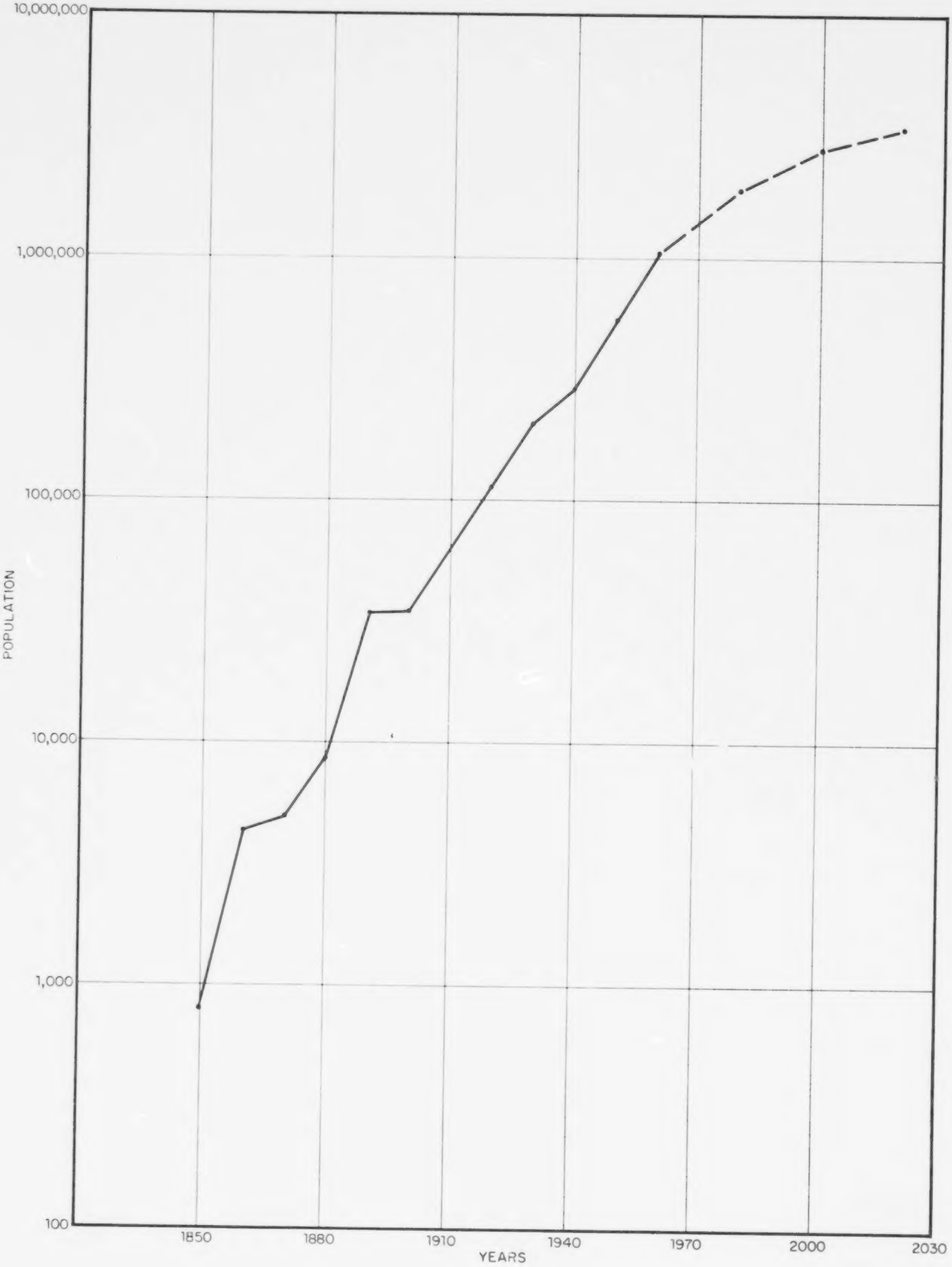


Figure 20

A view looking north over Mission Bay in January, 1968.
(City of San Diego)

Figure 21

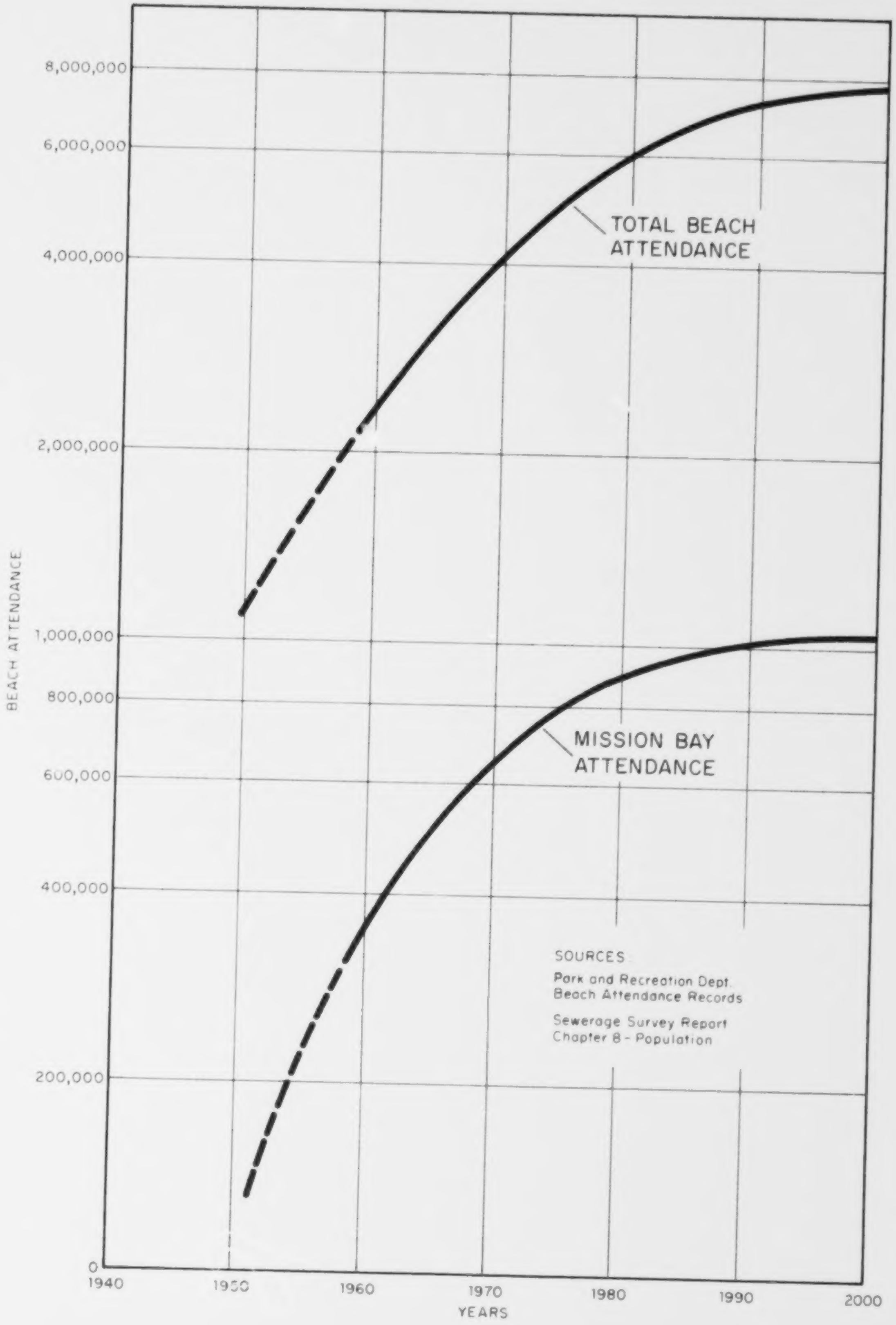
Historical and projected population of San Diego County. (From California Dept. of Water Resources Bulletin No. 112, 1964)


10,000,000
1,000,000
100,000
10,000
1,000
100
POPULATION
1850
1880
1910
1940
1970
2000
2030
YEARS

A-323

Figure 21 A

Past and projected beach attendance, San Diego Bay area. (From City of San Diego Planning Department, 1958)



SOURCES:

Park and Recreation Dept. Beach Attendance Records

Sewerage Survey Report Chapter 8 - Population

Some of the lease facilities developed on the Bay by 1965 are given in Table 2. This information was compiled by J. K. Patterson (1965) in an Engineering Department report of the City of San Diego. According to the Property Department of the City, the amount of private capital now involved in Mission Bay stands at approximately $22,500,000, illustrating the fact that the Bay development is continuing to grow. The City notes an optimistic anticipated investment of $8,400,000 from the private segment of the community in 1968 - 1969.

The activity areas in the present Bay are shown in Figure 22. Much of the success of Mission Bay Park and the appreciation which the public has for the area can be attributed to the Aquatic Division of the Recreation Department of the City of San Diego. The aim in the operating rules and regulations for the Park is clearly "Play Safely, Enjoy Yourself and Come Again".

Boating activity throughout the State of California continues to increase. No specific information is available for the Mission Bay facilities. The general level of activity of pleasure boating for several of the leading counties in the state is shown in Table 3. The trend in boating activities in San Diego County has been projected to the year 2000 by the San Diego Planning Department. The total number of boats of three categories in the County is shown in Figure 23. The San Diego County Assessor's records show that there were 24,333 licensed pleasure craft in the County in June 1968. The assessable number was 12,833 which compares very well with the projection made in 1958 by the Planning Department.

TABLE 2

Existing Lease Facilities Mission Bay

Type	Name	Location	Cost of Completed Facilities	Date Completed	Facilities Available
Motel	Bahia	Bahia Point NE'ly Ventura Blvd.	$2,000,000.00	1954	177 rooms - 60 with kitchen facilities. Main Dining Room seating capacity 120, Banquet Room seating capacity 150 to 175. Olympic size swimming pool. Sauna baths. Docking facilities for 45 boats. Sailboat rentals. Bahia Belle cruises nightly around Bay during summer. Coffee shops.
Motel	Islandia	Quivira Basin SW'ly Ventura Blvd.	2,100,000.00	1961	120 rooms. Dining Room seating capacity 120 Banquet Rooms seating capacity 150. Docking facilities for 150 boats. Fuel dock. Boat sales and boat rentals. Sport fishing fleet of 5 boats carrying 240 people. Coffee shop.
Motel	Vacation Village	West Vacation Isle W'ly of Ingraham St.	3,200,000.00	1962	200 rooms - 75 with kitchen facilities. Main Dining Room seats 150, Convention Hall seats 600. Smaller convention rooms seats 30 to 325. Par 3 - 18 hole golf course. 2 tennis courts, 3 swimming pools. Boat marine with sailboat rentals. Barefoot bar with live entertainment nightly.

TABLE 2 continued

Type	Name	Location	Cost of Completed Facilities	Date Completed	Facilities Available
Hotel Motel	Hilton Inn	Playa Pacifica West of Hwy 101	$3,400,000.00	1962	200 rooms. Dining Room, Restaurant Coffee Shop. Banquet and Convention facilities for 1,000. Boat dock. Sauna baths. Olympic size swimming pool and children's wading pool.
Motel	Catamaran Privately owned property fronting on Bay	Mission Blvd. & Pacific Beach Drive			88 rooms - 34 of which have Pullman type kitchens. Dining room capacity 264. Convention Hall seats 300. Swimming pool, sail boat rentals and Coffee Shop. Costs on this facility not listed, because property is privately owned and not on leased City property.
Trailer Park	De Anza Trailer Harbor	De Anza Cove off Hwy 101	2,250,000.00	1954	661 Trailer sites from $45 to $115 per month. Swimming pool.
Boat Sales & Repairs	Dana Marina	Dana Landing W'ly Ingraham Street	680,000.00	1956	Docking facilities for 205 boats. Boat sales and repairs. Fuel dock, bait, hardware, & tackle, snack bar, and all types of boat rentals.
Yacht Club	Mission Bay	El Carmel Point E'ly-Mission Blvd.	293,000.00		Membership about 500. Mostly a sailing club, and has about 350 boats. Slips available for 150 boats, the balance in dry storage, or ties to moorings.
Golf Course	Mission Bay	De Anza Area W'ly - Hwy 101	860,000.00	1954	18-hole par 3 and 4 night lighted golf course. Restaurant.

TABLE 2 continued

Type	Name	Location	Cost of Completed Facilities	Date Completed	Facilities Available
Marine Park	Sea World	E'ly of Ingraham Street	$4,300,000.00	1964	Marine shows, Aquariums, Japanese Village with pearl diving, outdoor dolphin show.
Boat Sales Storage Repairs	Perez Cove Marina	Perez Cove Marina	506,000.00	1962	Dry boat storage for boats. Boat docking for boats. Crane for removing boats from water.
Boat Sales Storage Sport Fishing	Seaforth Sport Fishing Corporation	Quivira Basin	110,000.00	1959	Facilities for canning fisherman's catch as they arrive.
Boat & Ski Club	S. D. Mission Bay Boat & Ski Club	Rose Creek	75,000.00	1965	Clubhouse - Launching ramps.
TOTALS			$19,774,000.00		

From City of San Diego Engineering Department report October 1965 by J. K. Patterson.

Figure 22

Map showing activity areas in Mission Bay. (From Aquatic Division, Recreation Department, City of San Diego)

ACTIVITY AREAS

Water Skiing - Entire Area east of Causeway bridges known as EAST BAY except Coves and narrow waterways marked with 5 MPH buoys. Skiing permitted sunrise to sunset.

North end of West Bay from buoys at Santa Clara Point to North Shore. Sunrise to 11:00 a.m. ONLY and 5:00 p.m. to sunset.

Landing and Take-Off from official designated areas ONLY. Such areas are identified by orange colored target signs. Landing on one side, take-off on other. Skiing prohibited in all other areas at any time.

Swimming - Swimmers are urged to swim in Official Swimming Areas where Life Guards are on duty 9:00 a.m. to 7:00 p.m. Swimmers are particularly cautioned against swimming or wading in water ski or speed boat areas.

Sailing - The entire Northwest Bay is allocated to sailing and controlled speed activities daily from 11:00 a.m. to 5:00 p.m. All power vessels moving in this area will be governed by the basic speed regulations and will at no time move at a speed in excess of 10 MPH. Sailboats should stay clear of water ski and speed boat areas.

Fishing - Fishing is permitted any place in the Bay except official swimming areas and areas designated as water ski landing and take-off areas. It is expected that fishermen in boats will stay clear of water ski and speed boat areas.

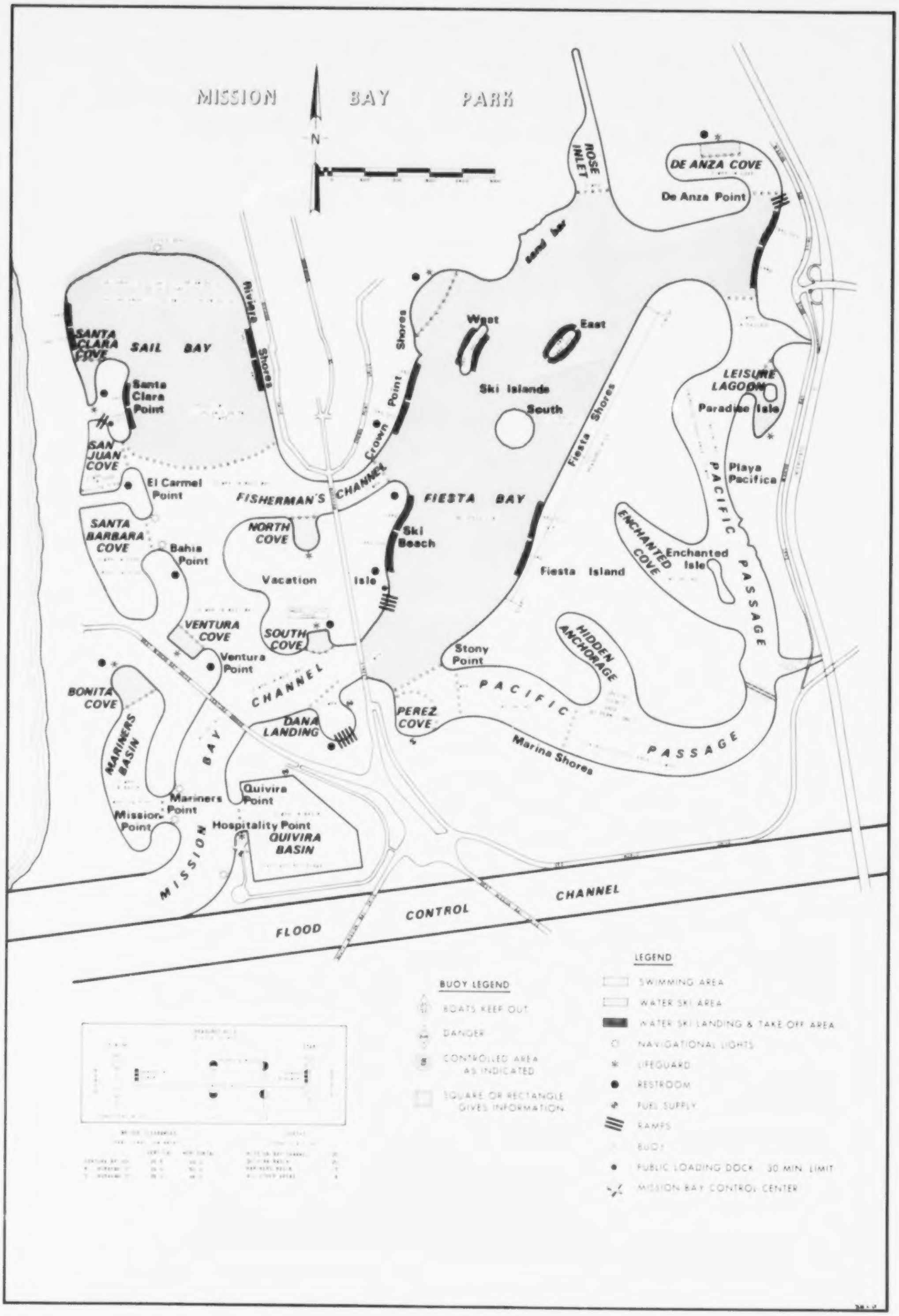

MISSION BAY PARK
N
ROSE INLET
DE ANZA COVE
De Anza Point
Sand bar
Riviera Shores
SANTA CLARA COVE
SAIL BAY
Santa Clara Point
SAN JUAN COVE
El Carmel Point
West
East
Ski Islands
South
Crown Point Shores
LEISURE LAGOON
Paradise Isle
Playa Pacifica
Fiesta Shores
FISHERMAN'S CHANNEL
FIESTA BAY
SANTA BARBARA COVE
Bahia Point
NORTH COVE
Ski Beach
Vacation Isle
ENCHANTED COVE
Enchanted Isle
PACIFIC PASSAGE
Fiesta Island
VENTURA COVE
SOUTH COVE
Ventura Point
HIDDEN ANCHORAGE
Stony Point
BONITA COVE
CHANNEL
PACIFIC PASSAGE
MARINERS BASIN
DANA LANDING
PEREZ COVE
Marina Shores
BAY
Quivira Point
Mariners Point
Mission Point
Hospitality Point
QUIVIRA BASIN
MISSION
FLOOD CONTROL CHANNEL
BUOY LEGEND
BOATS KEEP OUT
DANGER
CONTROLLED AREA AS INDICATED
SQUARE OR RECTANGLE GIVES INFORMATION
LEGEND
SWIMMING AREA
WATER SKI AREA
WATER SKI LANDING & TAKE OFF AREA
NAVIGATIONAL LIGHTS
LIFEGUARD
RESTROOM
FUEL SUPPLY
RAMPS
BUOY
PUBLIC LOADING DOCK 30 MIN. LIMIT
MISSION BAY CONTROL CENTER

TABLE 3

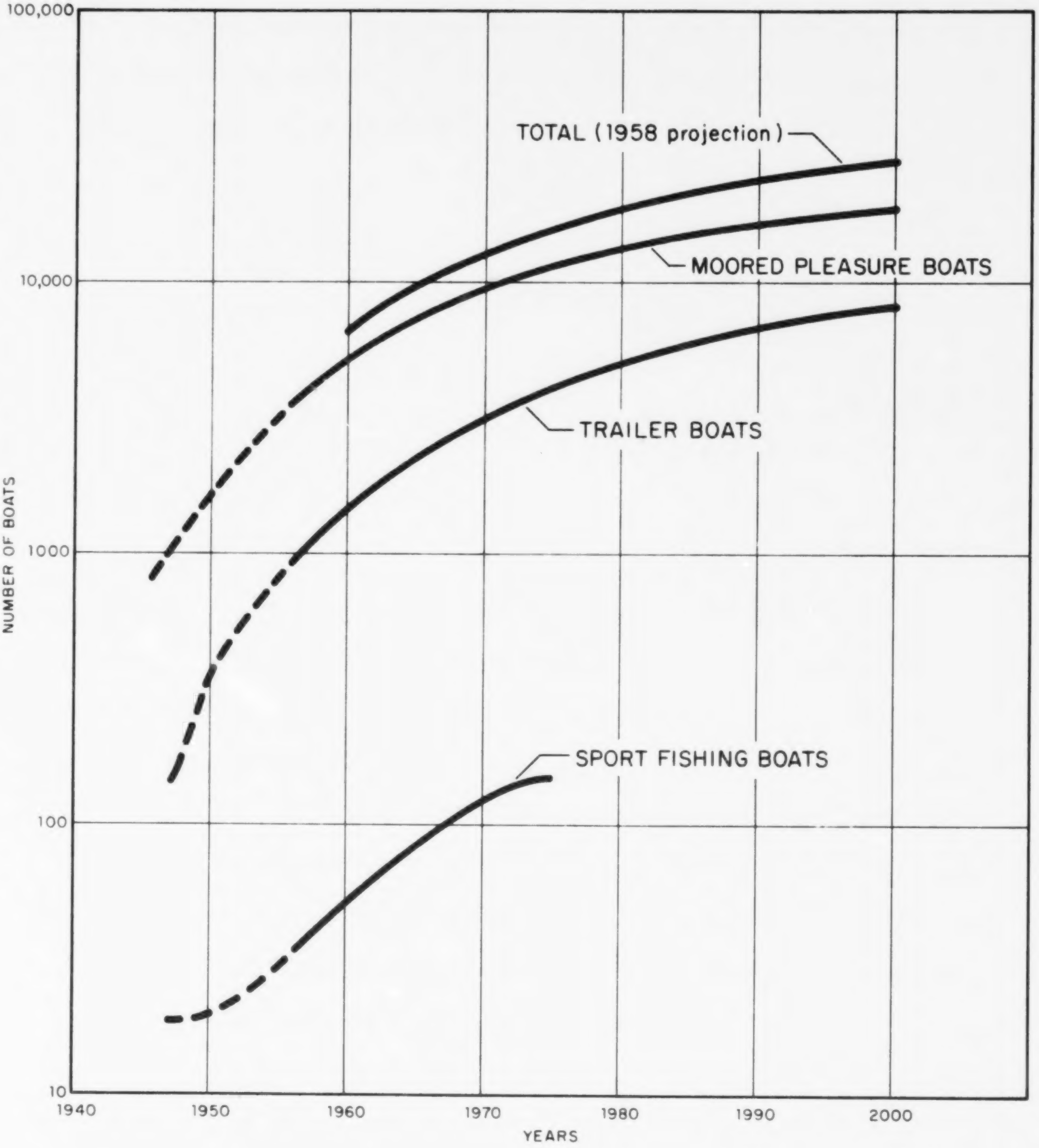
Pleasure Boating Activity in Selected California Counties
(More than 10,000 Pleasure Boats in 1967)

	Privately Owned		County Total	
County	1966	1967	1966	1967
Alameda	21,785	23,043	21,919	23,157
Contra Costa	17,606	18,948	18,256	19,566
Fresno	9,224	10,002	9,441	10,235
Los Angeles	98,554	103,186	99,335	104,031
Orange	22,961	27,889	23,629	28,468
Sacramento	22,216	23,567	22,705	24,069
San Bernardino	11,503	12,355	12,039	13,022
San Diego	19,862	21,848	20,573	22,245
San Joaquin	8,940	9,966	9,300	10,388
San Mateo	10,808	11,627	10,907	11,701
Santa Clara	16,158	19,546	16,267	19,689

Source: California State Department of Harbors and Watercraft, Report of Economic Survey Series, Research Department, California State Chamber of Commerce.

Figure 23

Graph showing number of boats in San Diego County. (From Economic Bulletin, v. XVI, no. 10, October 1968, San Diego)


100,000
10,000
1000
100
10
NUMBER OF BOATS
1940
1950
1960
1970
1980
1990
2000
YEARS
TOTAL (1958 projection)
MOORED PLEASURE BOATS
TRAILER BOATS
SPORT FISHING BOATS

078<

Capital Investment Summary

The City of San Diego has brought the summary of capital investment in Mission Bay Park up-to-date. Their figures are approximate, but show the following for the period 1945 through 1968:

Private Capital	$ 22,536,442.00	
State of California	3,208,000.00	
Federal Government	10,071,000.00	
City of San Diego	19,773,344.00	
Total	$ 55,588,786.00	
Anticipated 1968 - 69		
Private (Optimistic)	$ 8,460,979.00	
City (Factual)	1,727,200.00	
Total	$ 10,188,179.00	
Total through June 1969 -		$ 65,776,965.00

The office of the Property Department of the City of San Diego notes that there has also been considerable improvement of adjacent fee-owned lands directly attributable to Mission Bay Park's development.

Future Developments - San Diego River

There are authorized flood control projects for the river system which have not been started. The U. S. Army Corps of Engineers (1967) describes the San Diego River (Mission Valley) project which was authorized by the 1965 Flood Control Act. The project consists of a large channel through Mission Valley and three smaller ones described in Table 4.

TABLE 4

Physical Data on the Project Authorized by the 1965 Flood Control Act

Drainage area	435 square miles
Type of channel	Rectangular, concrete-lined
San Diego River (Mission Valley) channel:	
Length	27,600 feet
Capacity	115,000 cubic feet per second
Alvarado Canyon channel:	
Length	5,200 feet
Capacity	17,000 cubic feet per second
Murphy Canyon channel:	
Length	4,800 feet
Capacity	14,000 cubic feet per second
Murray Canyon channel:	
Length	2,100 feet
Capacity	6,000 cubic feet per second

The conditions existing in central Mission Valley in 1961 may be seen in Figure 24. The extension of the channel from the Bay into Mission Valley will protect a very extensive development which has taken place since Mission Bay was completed. A small part of the development is shown in the illustration. Two other major shopping centers and the San Diego Stadium with 50,000 seating capacity have been built since the photo of the valley was taken in 1961.

The Corps of Engineers has estimated the Federal first cost of the project at $16,100,000 (1966) while the non-Federal first cost is estimated at $8,500,000 (1966). In their 1967 report they state:

Figure 24

This 1961 photograph of Mission Valley illustrates the commerical development which has occurred. The San Diego River is reduced to a series of near-stagnant ponds. An extension of the flood control channel has been authorized for this area. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

> "The improvements will protect a rapidly developing area of commercial, industrial and resort-type property in Mission Valley. The overflow area to be protected comprises about 2,400 acres. If a project design flood should occur, the completed project would prevent flood damages estimated at $22,263,000".

Other activities of the U. S. Army Corps of Engineers which are related to the original estuarine system of the present study are listed in Table 5.

Development of San Diego Bay

The diversion dike along the San Diego River, which was finally made permanent in 1877, essentially isolated the river from part of its former estuarine system. San Diego Bay had other sources of fresh water so that isolating it from the San Diego River merely reduced the fresh water influx and shifted the major sediment deposition to the south portion of the Bay. Sediment brought to the Harbor by the San Diego River, whether it was the major source of supply or not, represented the most immediate threat to navigation. It was evident that continued deposition on the south side of the delta would have drastically changed the configuration of the deep harbor, possibly closing it permanently.

Development of lands adjacent to the Harbor was so extensive in the decades which followed the construction of the diversion dike that the community was forced to take further action in order to insure that the lands were protected from floods.

The relative importance of the river sediment with respect to the total sediment volume contributed to the Bay is undetermined. However, the

TABLE 5

Programs of the U. S. Army Corps of Engineers Related to the San Diego River Estuarine System

Name and District	Purpose	Approximate completion date
	NAVIGATION	
San Diego Harbor (Los Angeles District)	To review previous reports to determine the advisability of modifying the existing project. This investigation has been combined with the review investigation to determine the advisability of improving the small-craft harbor at Glorietta Bay, and establishing a small-craft harbor at Glorietta Bay, and establishing a small-craft harbor in the Roseville-National City-Chula Vista area. Interim report.	1967
San Diego Harbor, Second Entrance (Los Angeles District)	To determine the need for a second entrance into San Diego Harbor through the Silver Strand Peninsula.	Final Report 1968
	BEACH-EROSION CONTROL AND SHORE PROTECTION	
Imperial Beach (Los Angeles District)	To determine the advisability of modifying the existing project for beach erosion control at Imperial Beach and the need for beach erosion control in the reach from the Zuniga Jetty to the Mexican Border.	1968

TABLE 5 continued

Name and District	Purpose	Approximate completion date
	FLOOD CONTROL	
San Diego County Streams	To determine the advisability of providing flood-control, water conservation and related improvements on streams in San Diego County flowing into the Pacific Ocean. A series of interim reports is planned.	Indefinite

proximity of the delta to the entrance channel made this aspect of the San Diego River estuarine system a key factor if the deep harbor was to be preserved.

Documentation of the physical characteristics of San Diego Harbor and improvements which have been made can be followed through more than 100 years. The published reports of the United States Government pertinent to the overall San Diego Bay Project have been listed in Appendix I. This list was provided in an interim review of reports for navigation prepared by the U. S. Army Corps of Engineers (1967).

A summary of findings on the total commerce through San Diego Harbor is given in this review made by the Corps. It illustrates quantitatively the magnitude of present and future uses of a natural bay which were made possible as the result of controlling sedimentation in the San Diego River estuarine system. The summary prepared by the Corps is given in Table 6.

The purpose of the review investigation conducted by the Corps of Engineers was

> ". . . . to determine the need, the engineering feasibility, and the economic justification for (a) expanding and improving deep-draft navigation facilities in San Diego Harbor by modifying the existing projects; (b) establishing small-craft harbors in the vicinity of Glorietta Bay, Roseville, and National City-Chula Vista; and (c) rehabilitating and improving Zuniga jetty."

This shows the continuing efforts being made to improve and expand this harbor which is becoming one of the major seaports in western North America.

TABLE 6

Total Commerce Through San Diego Harbor in 1965 and in 10-Year Intervals for the Period 1970 to 2020 (U. S. Army Corps of Engineers, 1967)

Present and projected volume of total commerce (by type of cargo) through San Diego Harbor, Calif., 1965-2020 - in 1,000 short tons

Type of cargo	1965	1970	1980	1990	2000	2010	2020
Bulk	389	499	2,168	2,361	2,640	3,067	3,775
Other cargo	580	717	1,014	1,357	1,829	2,469	3,388
Petroleum:							
Bunker oil	30	39	103	112	121	132	143
Gasoline and distillate oils	378	378	378	378	378	378	378
Total	1,377	1,633	3,663	4,208	4,968	6,046	7,684

Present and projected volume of total commerce (by foreign and domestic totals) through San Diego Harbor, Calif., 1965-2020 - in 1,000 short tons

Year	Foreign		Domestic		Total
	Imports	Exports	Receipts	Shipments	
1965	232	488	631	26	1,377
1970	310	606	680	37	1,633
1980	477	2,322	816	48	3,663
1990	688	2,564	890	66	4,208
2000	982	2,915	977	94	4,968
2010	1,400	3,433	1,074	139	6,046
2020	1,972	4,310	1,186	216	7,684

Local interests have requested that a second entrance channel be provided in the Harbor. One proposed plan provided for a channel into the Harbor through the mouth of the Tia Juana River. The Corps is presently considering an alternate location with a channel through the Silver Strand. A model of the system is being evaluated at present.

The Corps cites continued port expansion, increased congestion in the north channel, construction of the Coronado Bridge, and planned conversion from fossil fuel to more sophisticated propulsion systems by the Navy as reasons for considering a second entrance not only economically justified in the future, but necessary from a safety standpoint.

The economic development of San Diego as an estuarine community is the subject of other studies of larger scope being conducted at present. For the purposes of this report, it will suffice to note a few of the major economic elements of the community related to the two bays. The Chairman of the Board of Port Commissioners has provided some useful information in this regard. The most significant single element in the local economy is the United States Navy. Expenditures of the Navy in this area in 1968 were approximately 1.4 billion dollars, about 25 percent of the local economy. Tourism in San Diego County in the same year amounted to over 350 million dollars. Much of this can be directly related to the marine environment. The commercial fishing industry in San Diego in 1968 had a 160 million dollar volume. Total dollar volume figures for waterborne commerce during the last year were not available but the City of San Diego realized approximately 16 million dollars from revenues related to this industry.

SEDIMENTATION

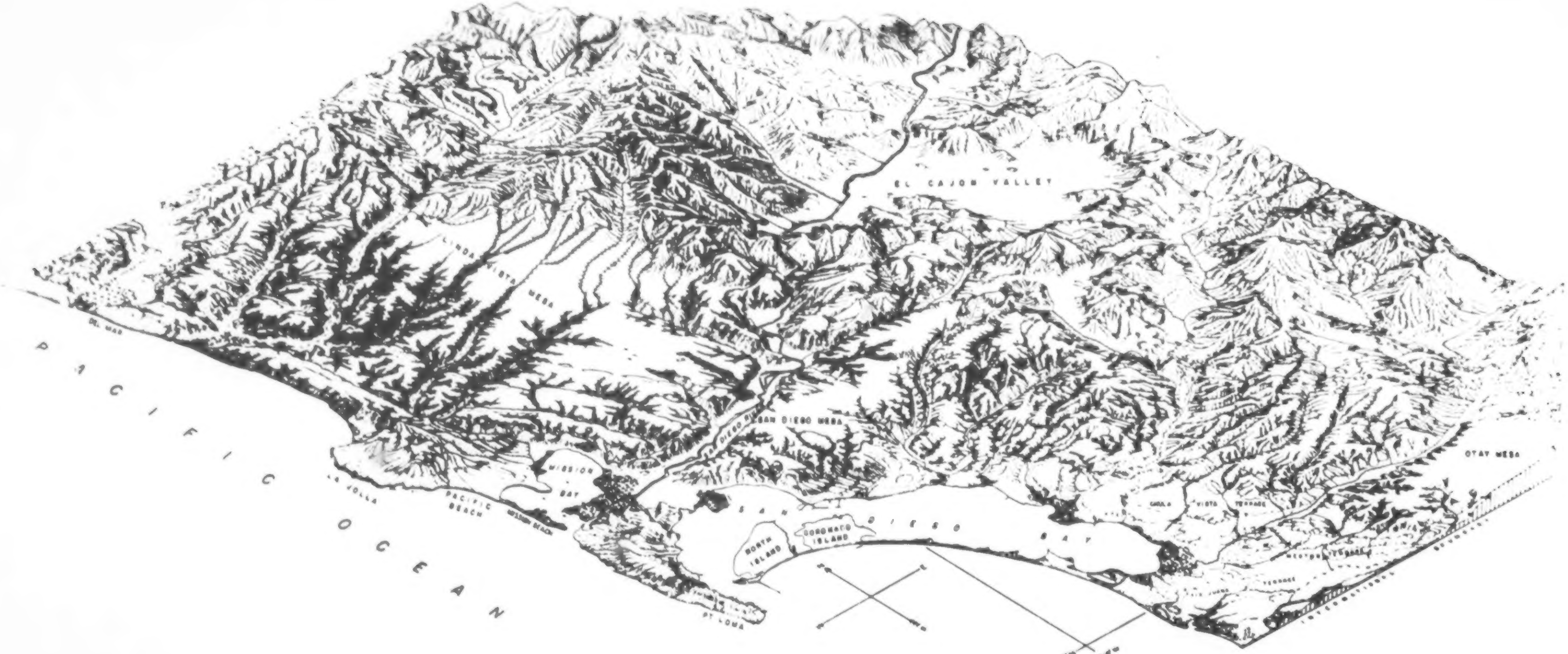
General Geology of the San Diego River Basin

The San Diego River Basin is a northeast-southwest drainage area extending from Volcan Mountain at the inland extremity (elev. 5700 feet) to Mission Bay on the Pacific Ocean. The total area of the basin is approximately 435 square miles. The maximum width of the basin is 14 miles and it is approximately 48 miles from Mission Bay to the crest of the mountains at the eastern boundary. According to data provided by the U. S. Army Corps of Engineers, the basin may be divided into three basic physiographic provinces. The mountain area is approximately 207 square miles. The terraces and valleys cover approximately 223 square miles. The coastal area is limited by the terraces or higher ground on three sides and is approximately 5 square miles. The western portion of the drainage basin is shown in the physiographic block diagram of Figure 25 (Nelson, 1956).

The lowlands and valleys along the river are differentiated by name simply for the purposes of discussion. The names and distances used herein apply along the axis of the basin. The tidal flats and delta are approximately miles 0 to 3. This area, as it was before significant development, is shown in Figure 15. Mission Valley, directly above the delta, extends from mile 3 to mile 13; Mission Gorge connects Mission Valley and the upper San Diego River Valley. Mission Gorge extends approximately from mile 13 to mile 16.

Figure 25

Physiographic block diagram of the San Diego and La Jolla quadrangles.
(From Hertlein and Grant, 1944)


EL CAJON VALLEY
LINDA VISTA MESA
DEL MAR
PACIFIC OCEAN
LA JOLLA
PACIFIC BEACH
MISSION BEACH
MISSION BAY
SAN DIEGO MESA
SAN DIEGO BAY
NORTH ISLAND
CORONADO ISLAND
PT. LOMA
CHULA VISTA TERRACE
OTAY MESA
INTERNATIONAL BOUNDARY

Physiographic Block Diagram of the San Diego and La Jolla Quadrangles and Some of the Mountainous Region to the East

(Drawn by E. H. Quayle)

The upper valley area includes El Cajon Valley and extends to El Capitan Reservoir.

The mountain area lies primarily above El Capitan Dam, although the lowland areas extend to the inland limits of the reservoir.

The general geology of the San Diego River is included here in order to define the gross characteristics of the source rocks of sediment which has been, or potentially could be, deposited at the mouth of the river. The geology of San Diego County has been described more thoroughly by others in numerous publications including Weber (1963), Hertlein and Grant (1944), and Ellis and Lee (1919).

The high areas adjacent to the river delta (Mt. Soledad to the north and the ridge highland of Point Loma to the south) are Cretaceous brown sandstone, conglomerate and shale. The boundary of Mission Bay is Recent alluvium and Pleistocene terrace deposits and dissected alluvium. Crown Point (Figure 26), which extends into Mission Bay from La Jolla highlands on the north, is an example of these terrace-type deposits. The San Diego and Linda Vista Mesas (Figure 27) above the delta on the east are dissected alluvium of marine and nonmarine sand and gravel with cobble and boulder conglomerates.

Mission Valley was formed by the river in the terrace deposits and has been cut into the San Diego formation, the Poway conglomerate and the Rose Canyon shale. The San Diego formation in this area is a micaceous marine sandstone of Pliocene age. The Rose Canyon shale is exposed in the lower

Figure 26

A 1917 view looking south toward Mission Bay. The prominent feature jutting into Mission Bay is Crown Point. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

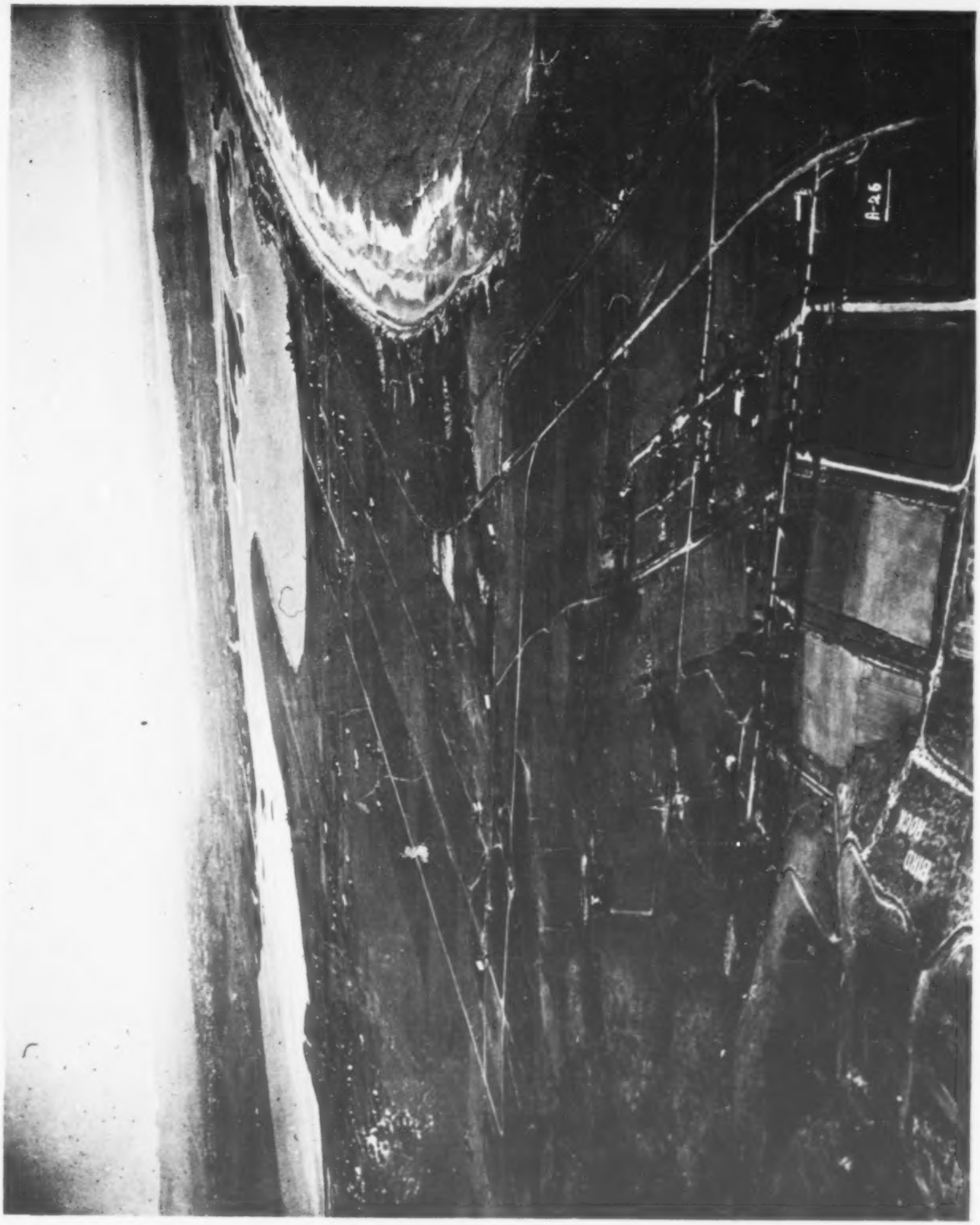
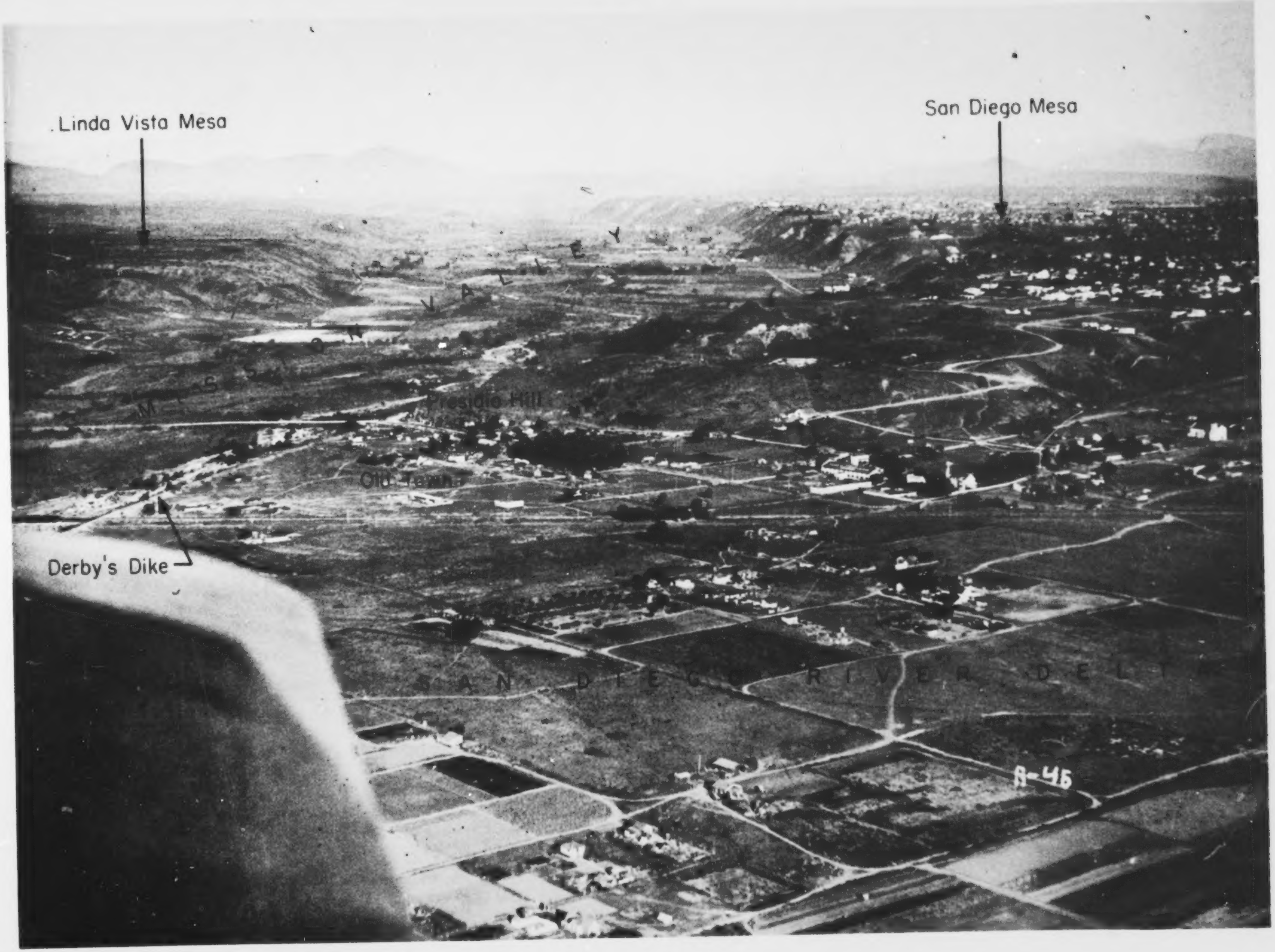

A-26
BIRD ROCK

Figure 27

This 1917 photograph shows the location of various topographic and geographic features frequently mentioned in the report. (Historical Collection, Title Insurance and Trust Company, San Diego, California)


Linda Vista Mesa
San Diego Mesa
MISSION VALLEY
Presidio Hill
Old Town
Derby's Dike
SAN DIEGO RIVER DELTA
A-46

portion of Mission Valley. This shale is gray to brown and was deposited in Eocene time. The Poway conglomerate is also Eocene and consists of conglomeratic sandstones and conglomerates. This formation crops out in the upper half of Mission Valley.

The river has exposed rocks older than the terrace deposits in the narrow valley known as Mission Gorge. These rocks are primarily Cretaceous quartz diorites with two exposed areas of metamorphosed volcanic bodies and sedimentary formations.

There are three distinct lithologic provinces between Mission Gorge and the mountains to the east along the axis of the basin. Below the two major reservoirs, San Vicente and El Capitan, the river valley is in Pleistocene terrace deposits and Recent alluvium. The minor tributary streams which join the river in this area cut into the Poway conglomerate and the same Cretaceous quartz diorites which are exposed in Mission Gorge. San Vicente and El Capitan reservoirs are almost completely within the quartz diorite outcrops. The quartz diorite outcrop forms the most extensive region in the central portion of the river drainage basin.

The higher portions and the drainage basin are almost entirely within siliceous igneous and metamorphic provinces. There are outcrops of basic rocks along the extreme southeastern and eastern boundaries of the basin. Some of the higher peaks such as Vijas Mountain (4173 feet), Poser Mountain (3919 feet), and Cuyamaca Peak (6515 feet) are outcrops of the Cuyamaca gabbro. Weber noted that the oldest rocks of the batholith of southern California are the gabbroic rocks. Another group of gabbros crops out in San Diego County northwest of the San Diego River basin. This group is the San Marcos gabbro which is closely related to the Cuyamaca gabbro.

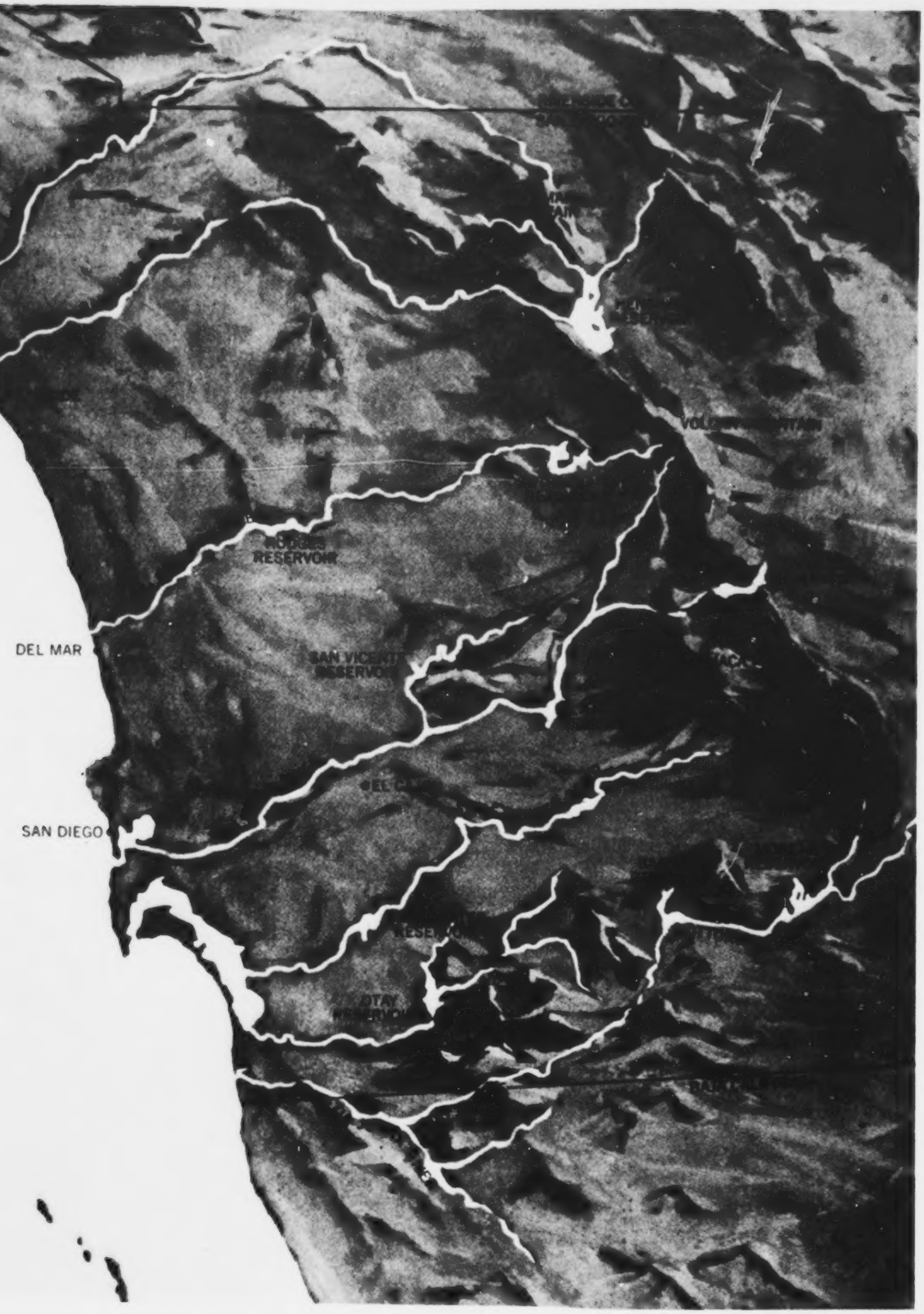
Recent Geologic History

The sketch map in Figure 28 illustrates the general course of the San Diego River and the trend of its basin at a time when the river flowed into False or Mission Bay. The most important changes in the basin pertinent to the present study have occurred in recent geologic history on the delta at the extreme west end of the area.

Deposition of the delta at the mouth of present Mission Valley progressed after the most recent glacial period to the point that two separate bays were formed by the delta reaching the Point Loma area. Drilling for various engineering projects in Mission Bay has shown that river gravels are generally present at 70 to 80 feet below the south half of the area. (The time when this portion of the Bay was a river channel can be estimated approximately, if emergence of the coastal region is ignored.) It appears that the river mouth was probably west of the present Mission Bay entrance about 10,000 years before the present. See Shepard (1963, p. 267) for a chronology of sea level rise during the last 19,000 years. These data indicate that deposition within the present limits of Mission Bay has been either marine or estuarine for approximately 10,000 years. It should be noted that this estimate is based on very general information. No studies related to the historical geology of the river delta have been made.

Figure 28

Sketch map of the rivers of western San Diego County.
(From Pourade, 1968)


VOLC TAIN
HODGES
RESERVOIR
DEL MAR
SAN VICENT
RESERVOI
EL C
SAN DIEGO
RESER
OTAY

Sediment Sources

The sediment basin of the present study area,before man's intervention,was supplied with gravel, sand, silt, clay and organic detritus from a number of sources as follows:

1. The San Diego River drainage basin supplied terrigenous material derived from weathering and erosion of igneous, volcanic, sedimentary and metamorphic rocks.
2. Local intermittent streams cutting through the Linda Vista and San Diego Mesas supplied sediment either directly to the two bays or indirectly through the San Diego and Sweetwater Rivers. Weathering and erosion agents in this case act on the nonmarine gravel or boulder conglomerates and finer grained sediments of the two mesas. See Tecolote and Rose Creeks in Figures 29 and 30.
3. The sedimentary rock highlands of the La Jolla and Point Loma areas supply sediment by drainage directly into the basin.
4. The biomass in the two bays produces an undetermined amount of material which may be preserved in the sediments.
5. Sand and silt are transported to the entrances of the bays from the adjacent coastline. The situation at the entrance to Mission Bay is shown in Figure 31.
6. A direct eolian contribution from the beach sands along the coast should be noted. The quantitative importance of this source is undetermined. The predominant sea breeze from the west-northwest moves fine-grained material almost on a daily basis from the beaches into the bays.

Magnitude of Sediment Input

No studies were ever made to determine the magnitude of sediment influx to Mission Bay and San Diego Bay when the river ran unrestricted across the delta or after the diversion dike was built. The Corps of Engineers

Figure 29

Tecolote Creek empties into Mission Bay.
(Historical Collection, Title Insurance and
Trust Company, San Diego, California)

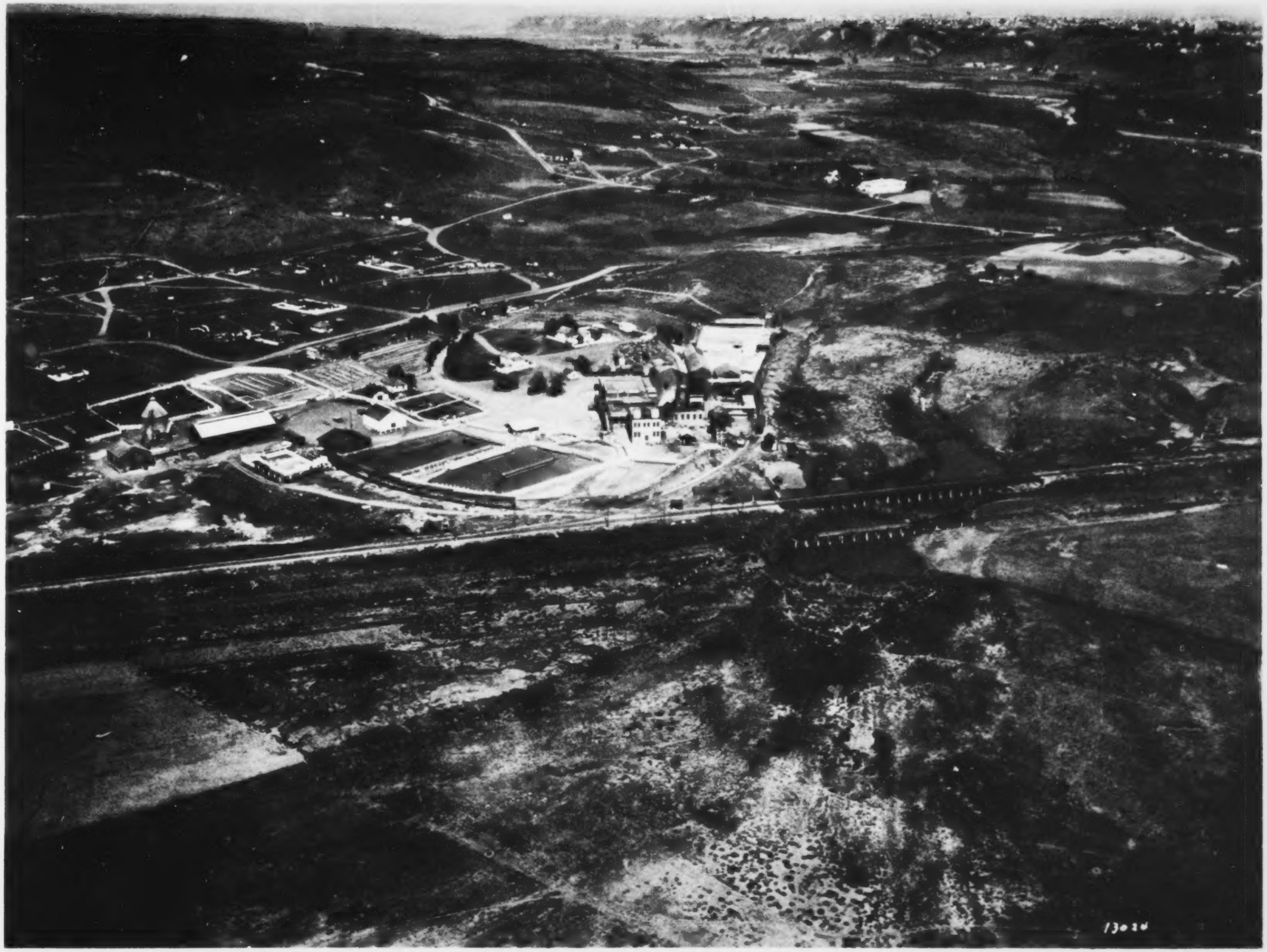

13020

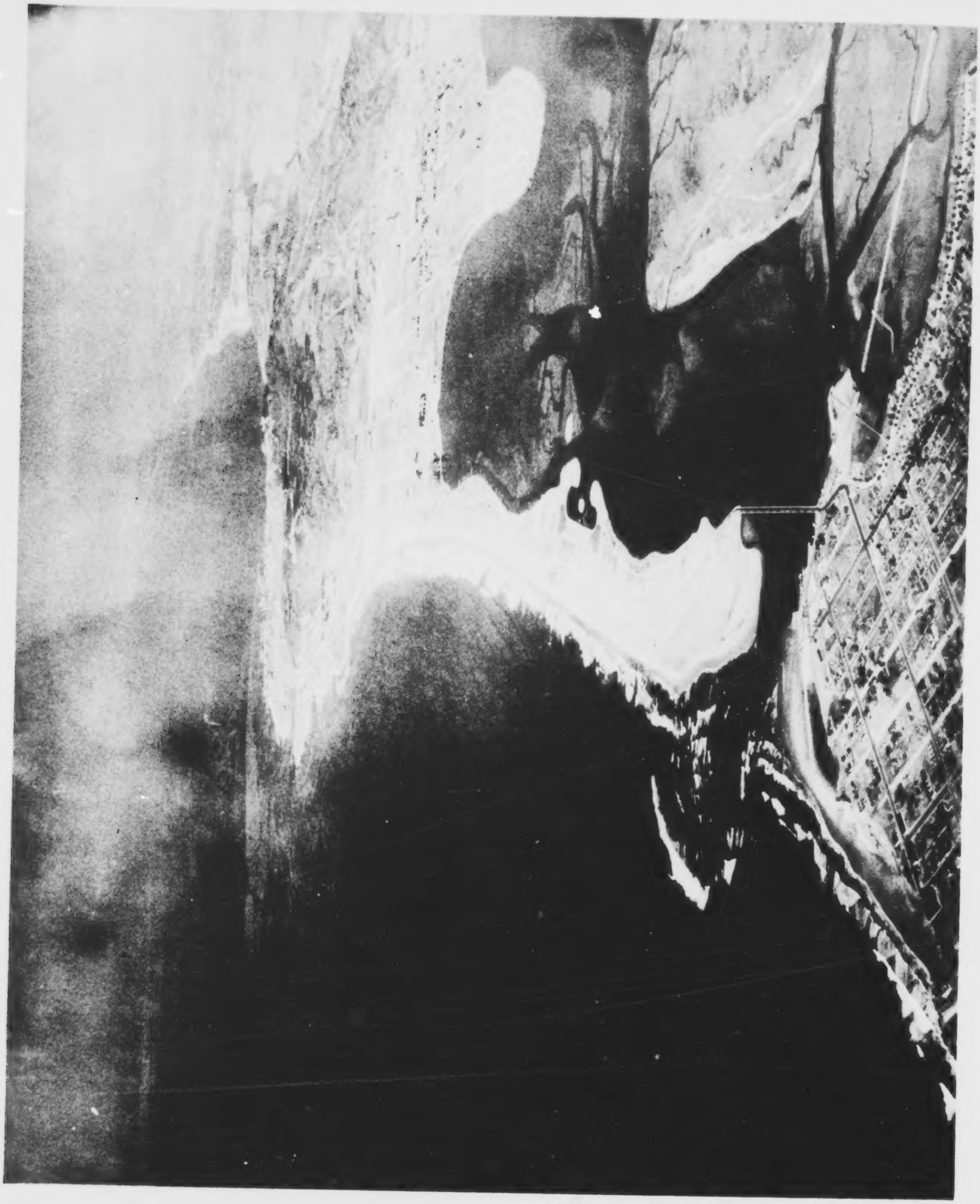
Figure 30

Looking north, this 1946 view shows Rose Creek, the eastern flank of Mount Soledad (left side) and the Linda Vista Mesa. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

46-90-9

Figure 31

A 1928 view looking upcoast over Mission Bay toward Point La Jolla. The entrance channel, Mission Beach, Bonita Basin and Mount Soledad are clearly visible in this photograph. (Historical Collection, Title Insurance and Trust Company, San Diego, California)



considers that the river is the most significant sediment source for the Mission Bay area. The San Diego Bay side of the delta is more complex because that became part of another estuarine system when the river was permanently diverted into Mission Bay. It appears from a comparison of the land areas involved in the six source categories listed in the previous section,that the river sediment potential is at least two orders of magnitude greater than the other sources. Sediment potential for a site or an area is defined as the expected yield of sediment from a given source or the expected depositional unit at a given site or area expressed in weight or volume units per time interval specified. Under most circumstances, the concept is applied at a site of expected deposition,but the volume amount is based on data from the source area. There are other applications of the term to littoral transport of sediment.

The California Department of Water Resources reports that the sediment potential of all drainage systems emptying into the Pacific Ocean will be the subject of a proposed study during the next several years. In the past, there has been no recognized need to evaluate the sediment input to the coastal region of the drainage of the San Diego River. The sediment supply to coastal regions in California, however, has long been recognized as a significant side issue in water conservation by private and governmental interests at all levels. Maximum utilization of surface water resources is essential in southern California. However, as this goal is realized, the beaches of the coastal region are progressively choked. Thus, the attempts to solve one economic and recreational problem create similar problems of comparable magnitude elsewhere.

Few sources of data were found which could be related directly to the magnitude of sediment input to the area of interest. The City of San Diego, Water Quality Division, has determined the change in water capacity of El Capitan Reservoir which now receives much of the runoff of the San Diego River. This reservoir has been accumulating sediment since 1934. The change in capacity of the reservoir was from 116, 500 acre feet in 1934 to 112, 807 acre feet in 1954. This change in capacity is equivalent to approximately 298, 000 cubic yards of sediment per year.

The U. S. Army Corps of Engineers (House Document 760) estimated the accretion on the San Diego River delta during the period 1876 - 1945. During this 69-year period, the average volume of sediment accretion was 540, 000 cubic yards per year. The accuracy of these data is undetermined, but the figure serves the purpose of establishing at least a reference magnitude of the sediment problem.

Sufficient data are available to make an estimate of the expected yield of sediment for the drainage basin by the method of Langbein and Schumm (1958). They compiled data from throughout the United States on sediment-gaging stations from the U. S. Geological Survey and on reservoir sedimentation which is collected by the Federal Inter-Agency River Basin Committee. The variations in precipitation distribution (chronological and geographical), soils, vegetation, runoff and land use are recognized. Langbein and Schumm attempted to establish an empirical means of estimating the gross variations in sediment yield associated with the climate as defined by the annual precipitation. Some of the land use and climatic data pertinent to the area are given for information in Tables 7 and 8.

The effective precipitation in an area has been used in this method and is defined as the amount of precipitation required to produce the known amount of runoff. This normalizes the values of annual runoff to a reference temperature of 50° F; thus, the effects of evaporation losses are accounted for.

The mountain region of San Diego County has a mean annual temperature of 57° F, and the lower areas have a mean temperature of approximately 63° F. This places the climate in our area of interest in a slightly warmer region than the 50° F reference temperature. This means that the effective precipitation is somewhat less than the actual in this study area. The mean precipitation for the total region is in the range 15 to 20 inches per year. The effective precipitation is assumed to be 15 inches per year, approximately at the peak of the curve taken from Langbein and Schumm which is shown in Figure 32.

The estimated yield by this method for the drainage basin which supplies El Capitan Reservoir is 291,000 cubic yards per year, and for the San Diego River as a whole is 643,800 cubic yards per year.

The conversion from tons of sediment per year per square mile is made assuming a dry density of sediment equal to 60 lbs. per cubic foot. This was the average of reported densities in the reservoir data.

TABLE 7

Land Use in 1958 in San Diego River Basin Downstream from El Capitan and San Vicente Dams To Mission Gorge

Category and class of land use	Area	
	In acres	In percent
Urban and Suburban		
Residential	3,770	
Commercial	370	
Industrial	20	
Unsegregated urban and suburban area	600	
Subtotals	4,760	
Included nonwater service area	2,280	
Gross urban and suburban area	7,040	9.6
Irrigated Agriculture		
Alfalfa	90	
Pasture	1,090	
Citrus and subtropical	1,770	
Truck crops	400	
Field crops	10	
Deciduous fruits and nuts	70	
Small grains	280	
Vineyards	40	
Subtotals	3,750	
Fallow	200	
Included nonwater service area	400	
Gross irrigated agriculture	4,350	6.0
Nonirrigated Agriculture	2,650	3.6
Native Vegetation	7,810	10.7
Unclassified	51,220	70.1
Totals	73,070	100.0

From California State Department of Water Resources Bull. 112, Sept. 1964.

TABLE 8

Climatic Data, 1953*

Coastal Plain, City of San Diego; Elevation: 19 feet

Month	Temperature Mean High	 Mean Low	 Mo. Mean	 Absolute High	 Absolute Low	 Days 32 or below	Precipitation Total
January	69.8	50.1	66.0	88	43	0	.58
February	68.1	45.9	57.0	84	38	0	.58
March	65.9	49.4	57.7	83	43	0	.79
April	64.6	53.2	58.9	70	44	0	.33
May	70.5	55.2	62.9	96	51	0	.09
June	70.6	58.9	64.8	77	55	0	.14
July	76.4	65.1	70.8	84	60	0	T
August	75.6	64.3	69.9	81	60	0	T
September	74.8	61.4	68.1	87	55	0	T
October	76.5	58.3	67.4	94	50	0	.07
November	72.5	53.6	63.1	89	45	0	.80
December	69.0	46.3	57.7	83	39	0	.03
Year	71.2	55.1	63.2	96	38	0	3.41

Foothill-Valley Region, Escondido; Elevation: 700 feet

Month	Mean High	Mean Low	Mo. Mean	Absolute High	Absolute Low	Days 32 or below	Precipitation Total
January	71.2	43.1	57.2	86	35	0	1.69
February	72.3	37.7	55.0	87	30	2	.91
March	72.5	41.8	57.2	88	33	0	1.54
April	70.5	45.1	57.8	83	33	0	1.40
May	77.6	46.5	62.1	91	40	0	.26
June	84.1	51.1	67.6	97	43	0	.09
July	93.2	58.9	76.1	104	52	0	0
August	90.3	55.7	73.0	98	50	0	0
September	90.3	53.6	72.0	103	46	0	0
October	86.4	51.5	69.0	106	42	0	.04
November	76.6	47.4	62.0	90	35	0	1.19
December	71.9	40.4	56.2	86	29	1	.28
Year	79.7	47.7	63.7	104	29	3	7.40

Mountain Region, Campo; Elevation: 2590 feet

Month	Mean High	Mean Low	Mo. Mean	Absolute High	Absolute Low	Days 32 or below	Precipitation Total
January	66.8	36.0	51.4	79	26	16	1.04
February	63.8	26.7	45.3	79	14	22	1.05
March	64.9	31.5	49.2	79	22	20	2.28
April	66.5	34.5	50.5	82	20	11	1.24
May	70.6	36.0	53.3	83	29	9	.49
June	83.4	40.8	62.1	101	31	1	.01
July	94.9	56.3	75.6	102	46	0	.04
August	92.3	51.2	71.8	102	37	0	.01
September	91.9	45.7	68.8	101	35	0	0
October	79.6	40.0	59.8	92	29	4	0
November	71.1	38.5	54.8	85	22	6	1.14
December	63.2	32.1	47.7	76	19	17	.18
Year	75.7	39.1	57.4	102	14	106	7.48

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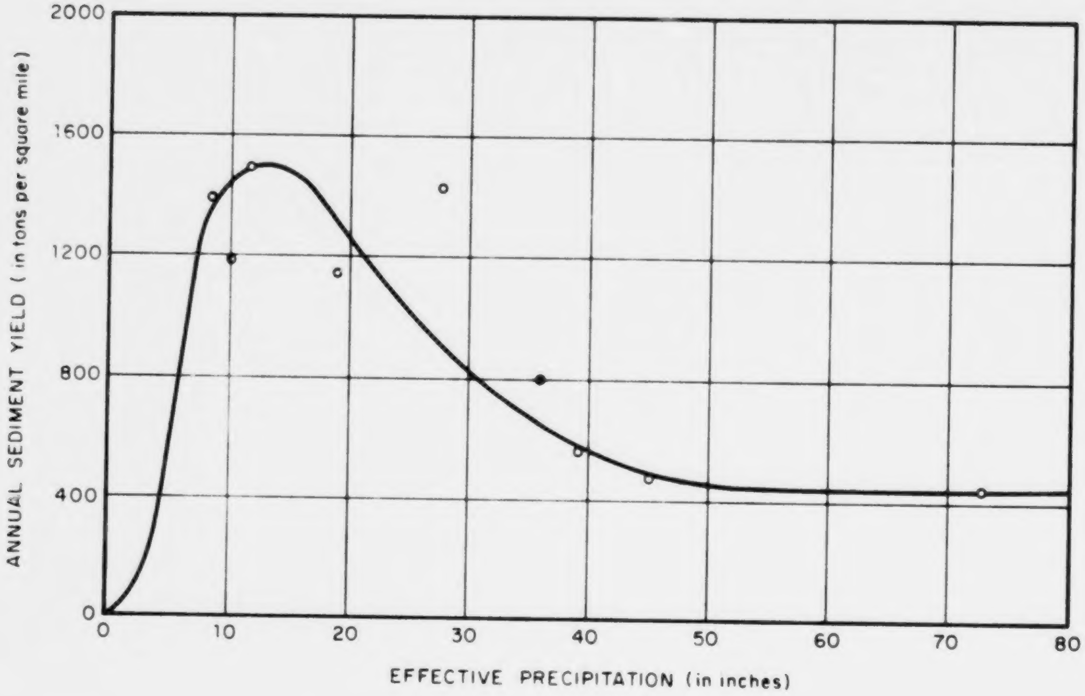
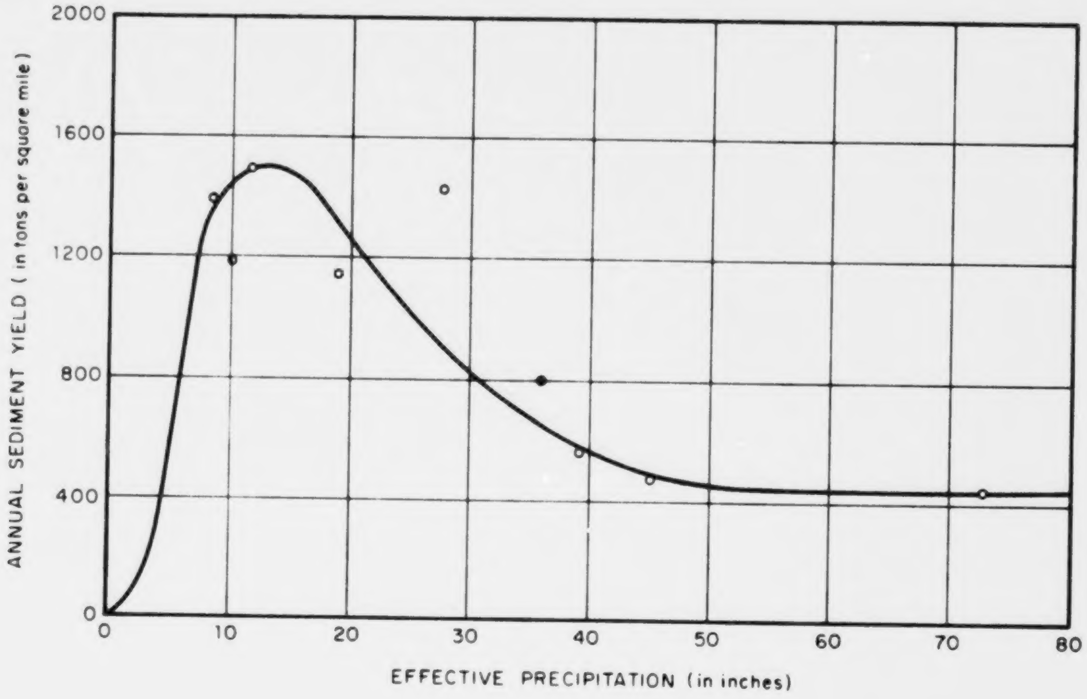
* San Diego County Natural Resources. Annual Report No. 10, (San Diego: Department of Agriculture, Division of Natural Resources, County of San Diego, 1954).

Figure 32

Climatic variation of yield of sediment as determined from reservoir surveys. (From Langbein and Schumm, 1958)


2000
1600
1200
800
400
0
ANNUAL SEDIMENT YIELD (in tons per square mile)
0
10
20
30
40
50
60
70
80
EFFECTIVE PRECIPITATION (in inches)


ANNUAL SEDIMENT YIELD (in tons per square mile)
2000
1600
1200
800
400
0
0
10
20
30
40
50
60
70
80
EFFECTIVE PRECIPITATION (in inches)

The agreement between the empirical estimate and the accumulation data is fortuitous. This does not necessarily mean that the sediment input volume has been established with any degree of accuracy, but it can be said that the long-term annual sediment input is very likely in the range of 500,000 to 700,000 cubic yards per year.

Causes of Deposition

Sediment has collected in the San Diego Bay - Mission Bay basin through the natural sedimentary cycle of weathering, erosion, transportation and sedimentation. The configuration of part of the drainage basin and its relation to the depositional basin and the local marine environment can be seen in the physiographic block diagram in Figure 25. During recent geological history, the depositional environment changed from a delta in the marine environment to a delta in an estuarine environment. The transition from a primarily marine situation probably occurred when the sediment prism in the river delta closed the gap between the mainland and the present Point Loma highland which had been an island prior to that time.

The delta at the present sea level was broad enough for the mouth of the meandering river to alternate between Mission Bay and San Diego Harbor west of Presidio Hill. During periods when the river was emptying into San Diego Harbor, the sediment supply for Mission Bay was essentially reduced to that contributed by Rose Creek (Figure 30) coming into the Bay from the northeast and other smaller streams which drain Linda Vista Mesa and the small drainage adjacent to the Bay on the north and south.

The causes of sedimentation of organic debris are the natural life cycles of the flora and fauna in the water and in the inter-tidal zone of the Bay. The relative importance of the organic contribution to bay sediments is undetermined. MacDonald (1967) has examined the distribution of biomass in a small portion of Mission Bay. This work was part of his larger study of salt marshes of the Pacific coast. The data cannot be extrapolated to a determination of total organic production in the Bay. No other specific studies have been made in Mission Bay or San Diego Bay related to the organic contribution to sedimentation.

The natural causes of sediment deposition have not been changed significantly by flood or sediment control efforts in the system. The rates of deposition and the characteristics of the environment in Mission Bay have undergone two periods of adjustment in recent history. The first followed the separation of the two bays by the delta. The second period followed the confinement of the river in the present flood control channel. The delta and bays could tend toward stability during these periods. The major difference between conditions in Mission Bay now and in previous periods is the fact that some control on the physical setting of the bay is being exerted.

When Mission Bay was designed, consideration was given to limiting the physical changes which could be expected from natural littoral processes. These design considerations and the basis of each are discussed in the section on development of Mission Bay. The primary causes of sediment deposition in Mission Bay at present, if it is realistic to define them in the context of man's intervention, are the littoral processes which are actively reworking sediments already present.

Water Supply

The causes of sediment deposition in a semi-arid climate such as that found in San Diego County cannot be examined without considering the historical problems of water supply in the region. Man has tampered with the natural sedimentary cycle in the San Diego River basin for over a century. The earliest documented examples of man's intervention are related to preserving the water.

The state of the water resources in the late 1770's was described by a Franciscan missionary, Fr. Francisco Palóu:

> "As this mission lacks water for irrigating the extensive and fertile land which it possesses, the inmates must suffer want, unless the crops turn out well. The first two years have proved this. In the first year, the river rose so high (though it has running water near the mission only in the rainy season), that it carried away all that had been sown. In the second year, planting was done farther back of the stream. During the greater part of that season, however, the water was scarce so that the plants perished. Only five fanegas of wheat were secured, and these were used for sowing in the locality about two leagues from the mission, because from experience it was learned that in said place rain was more frequent. The country has been surveyed for a distance of 10 leagues in every direction; but no running water for irrigation has been discovered. Only for the livestock is there in various places sufficient water and abundant pasture."

Attempts were made to alleviate the critical water supply problem early in the 19th century. In 1807, construction of an aqueduct and dam in Mission Gorge was begun. This project lasted nearly a decade. Pourade (1961) describes the structure:

> "It was 244 feet long, 13 feet thick, 13 feet high and had a gate and spillway. The river ran the year around at this site, before it dropped through the canyon and in dry periods lost itself in the sands of Mission Valley. But the mission was six miles away, down an almost impenetrable rock canyon. The padres drew the water off on the right or north side, and ran it through an open tile aqueduct, by gravity flow, all the way down the canyon and then to the mission. The dam itself

> impounded about 20-acre feet of water, which when carried down the gorge, was stored in a settling basin near the mission. The structure included a sand trap, to clear the water before it entered the flume, and a 4-inch penstock through which the water was forced by a pressure chamber apparently to turn the wheel of a grist mill."

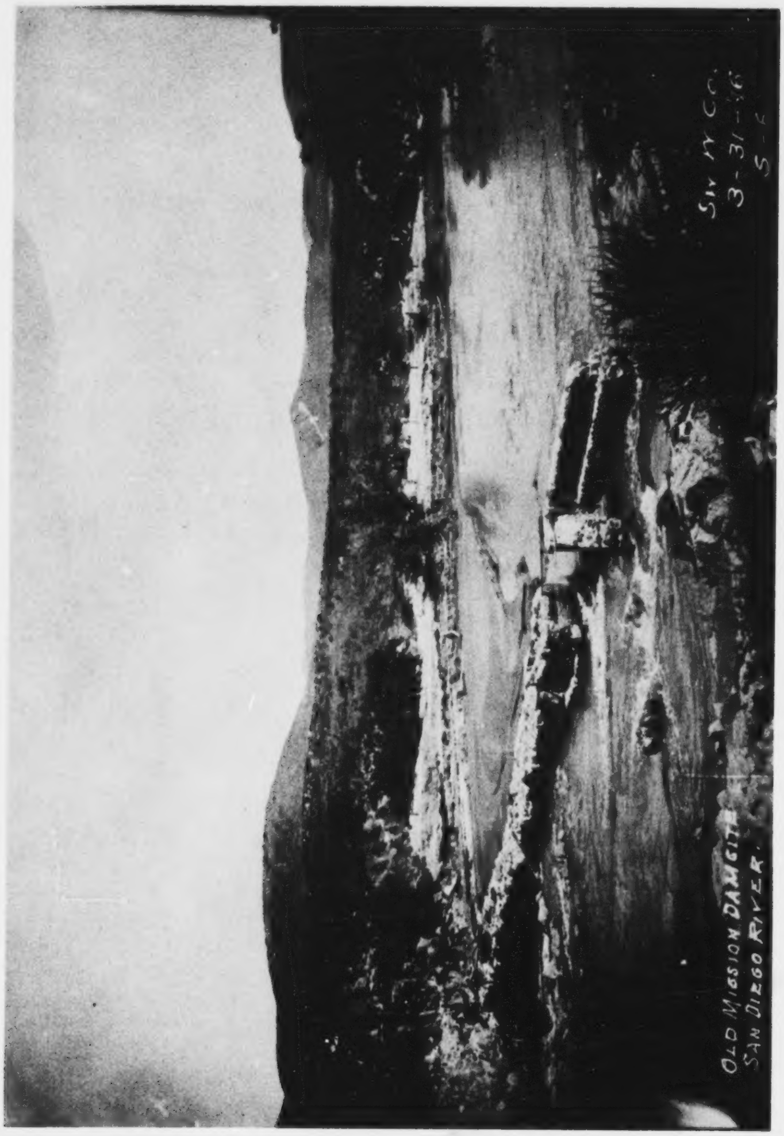
A photograph of Old Mission Dam during the flood of 1916 is shown in Figure 33. This flood carried away much of what remained of the original structure after one hundred years.

Water for the new settlement of San Diego was still a problem in 1850; a daily water train was dispatched to bring water from the San Diego River near Old Town. In 1886, the San Diego Flume Company began construction on Cuyamaca Dam at the head of Boulder Creek and on an aqueduct which would carry water to San Diego 30 miles away. This long aqueduct was completed in 1889. The condition of the river prior to the completion of the aqueduct is shown in two views of dry Mission Valley in Figure 34. Pourade (1964) describes the ambitious aqueduct project:

> "During dry seasons the water was to be released from the Cuyamaca Reservoir and let flow twelve and a half miles down Boulder Creek to another dam on the San Diego River, at which point it would be diverted into the flume and carried down the south side of the San Diego River to El Monte Tunnel, about two miles east of Lakeside. From there the water was to be turned south to follow around El Cajon Valley to a terminus at a small reservoir. Here it was to be fed into a steel pipeline laid on the mesa for about ten miles and then into the city mains.
>
> The terminal storage, Eucalyptus Reservoir, on a small branch of Alvarado Canyon, was not completed until the following year. A second, known as Grossmont Reservoir, was built soon afterward. San Diegans, eager for prospects, hailed the flume as the most important enterprise in the history of the county and said it assured the irrigation of from 40,000 to 80,000 acres of land."

Figure 33

Old Mission Dam during the 1916 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)



SIV W CO.
3-31-16
5-E

OLD MISSION DAM SITE
SAN DIEGO RIVER.

Figure 34

Two views of Mission Valley photographed from the same lookout circa 1887. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

Looking east.

Looking west.

Water supply development for the City of San Diego subsequent to the aqueduct construction was supported by numerous bond issues. These projects dealt with the Sweetwater River and Cottonwood Creek and, although very interesting, are outside the scope of this study. Large-scale exploitation of the San Diego River as a source of water was rather late in coming. In December 1931, voters approved an expenditure of $3,600,000 for construction of El Capitan Dam.

Flooding of San Diego River

Floods on the San Diego River commonly resulted in a change in river course on the delta. This is a natural process on most deltas. There are several vague historical references to flooding in San Diego. The first specific flood mentioned in the literature occurred in the autumn of 1821. Apparently some damage was caused in Old Town to various private properties. The quality and quantity of flood documentation increases in later years. Lieutenant Derby's study of the San Diego area dealt with the flood problem and the threat it posed for the deep harbor south of Old Town. This study, which is discussed in another section of this report,resulted in construction of a diversion dike on the delta to isolate the San Diego side from the river. This dike failed during heavy rains and flooding in 1855.

A storm in March 1867 caused considerable damage. More than 5 inches of rain fell during the storm and caused flooding which carried away roads and bridges along the River. Between November 1873 and March 1874, 30 inches of rain fell in the San Diego area. The river went on a rampage on the morning of 18 January 1874. The flood in Mission Valley and Old Town carried away houses, trees, livestock and everything else in its path. The railroad bed and all roads were washed out, and observers on Presidio Hill said that the entire area between them and Point Loma was completely inundated.

The storm that struck San Diego during February 1891 is reputed to be the worst on record. Heavy rains and gale winds combined to destroy all developments on the floor of Mission Valley and on the San Diego River delta. Mission Valley, in a moderately wet period, is shown in Figure 36, a photograph of 1898.

No summary of storm and flood cases would be complete unless the notorious rain of January 1916 was included. This particular storm was attributed to Charles M. Hatfield, the renowned rainmaker. On 8 December 1915, Hatfield offered to fill the Morena Reservoir for the sum of ten thousand dollars, or furnish 30 inches of rain free and collect $500 per inch from the 30th to the 50th inch. All rain above 50 inches was to be gratis. The hilarity of the situation dissipated when nearly 13 inches of rain fell between the 14th and 17th of January. That was just the beginning. The following storm from the 23rd to the 29th of January raised the total rainfall to 35 inches. Hatfield did not collect from the City. The flood was a diaster. Dams failed, bridges collapsed, and roads, houses and other structures were destroyed by the rampaging waters. Photographic evidence of the 1916 flood is shown in Figures 37 through 42. This flood reached a discharge of 70, 200 cubic feet per second (Pourade, 1968).

Figure 35

High water in the San Diego River in 1889. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

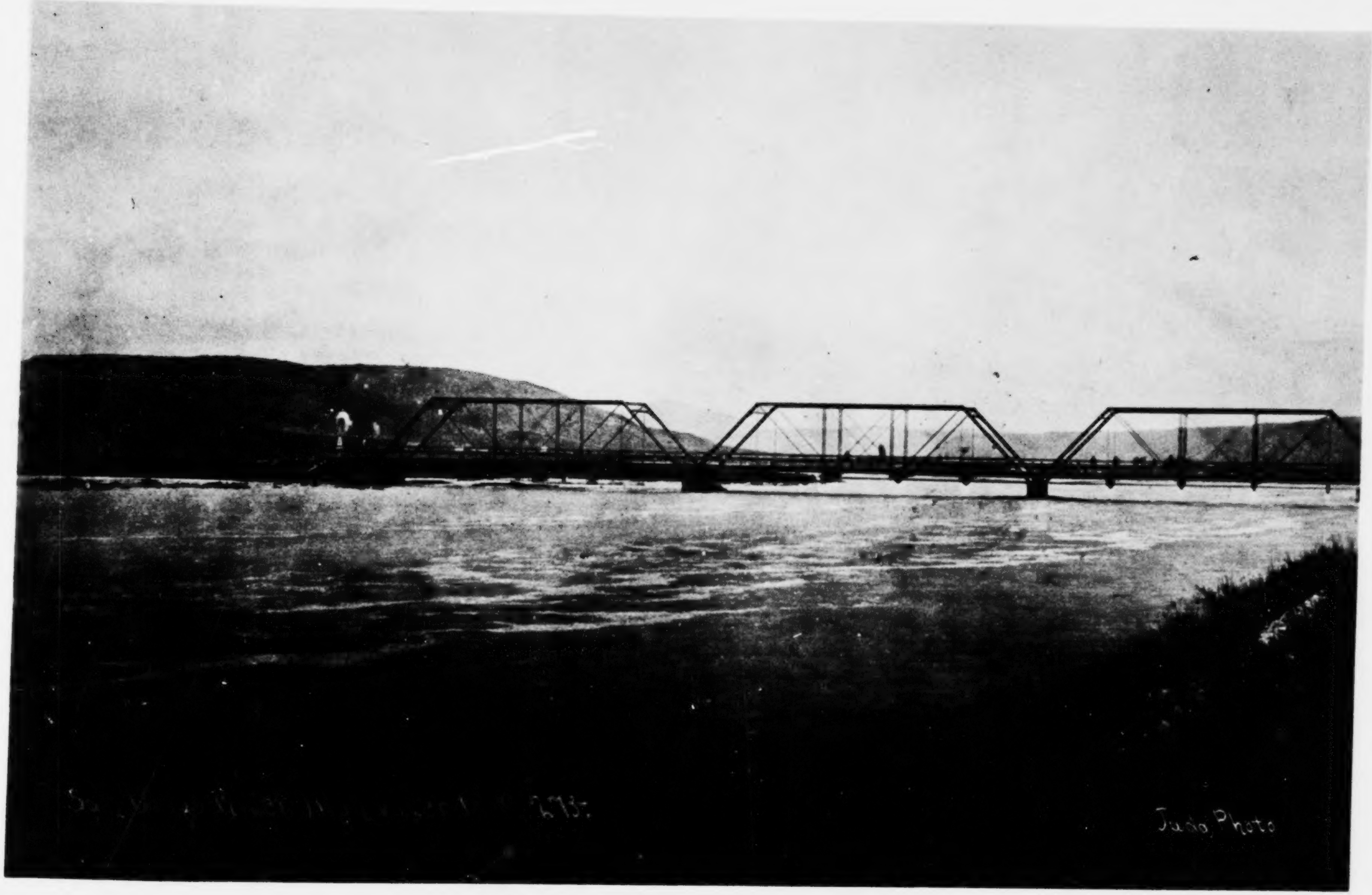

Judd Photo

Figure 36

A view looking east of Mission Valley in 1898. (Historical Collection, Title Insurance and Trust Company, San Diego California)

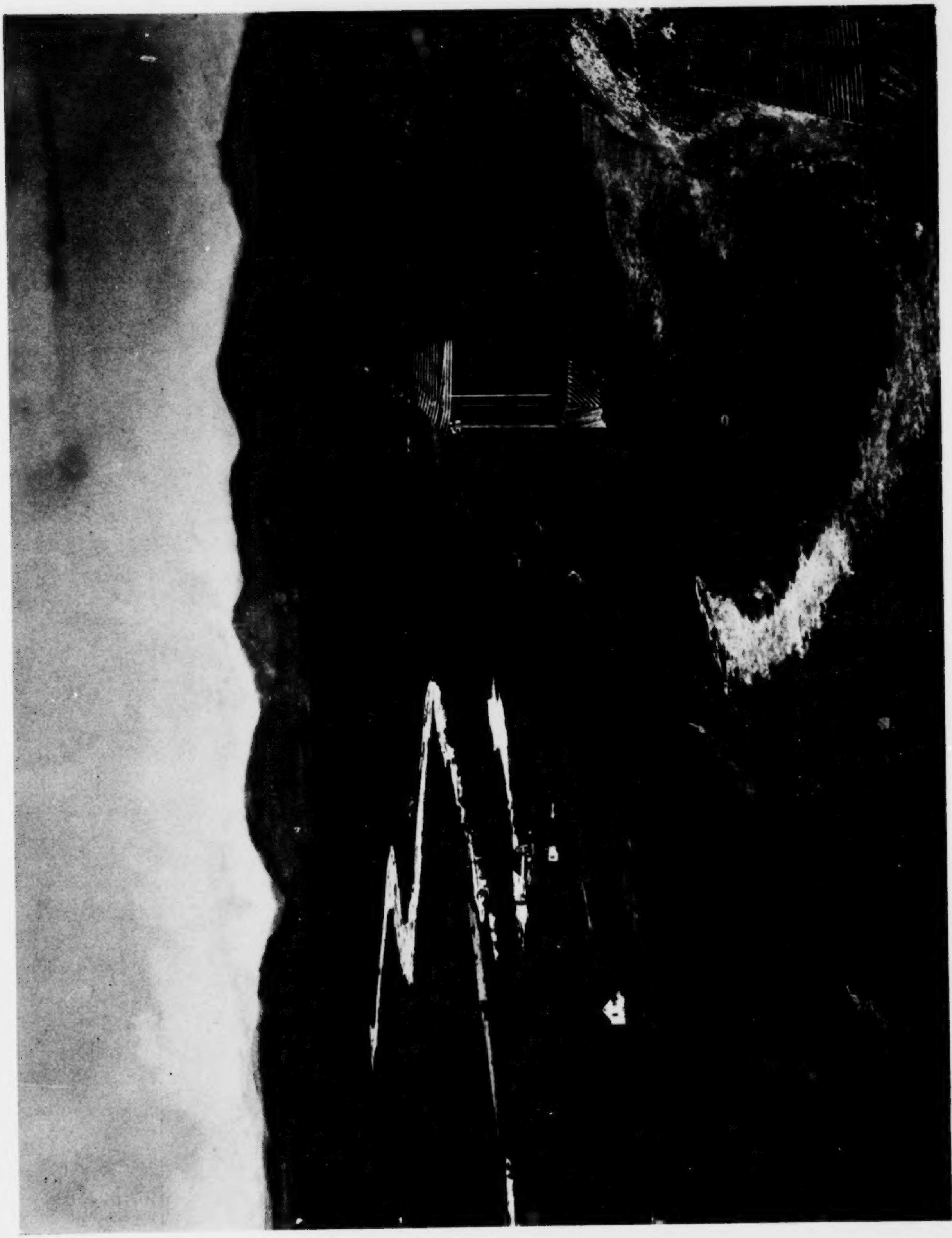


Figure 37

Flooding in Mission Gorge during 1916 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

2067

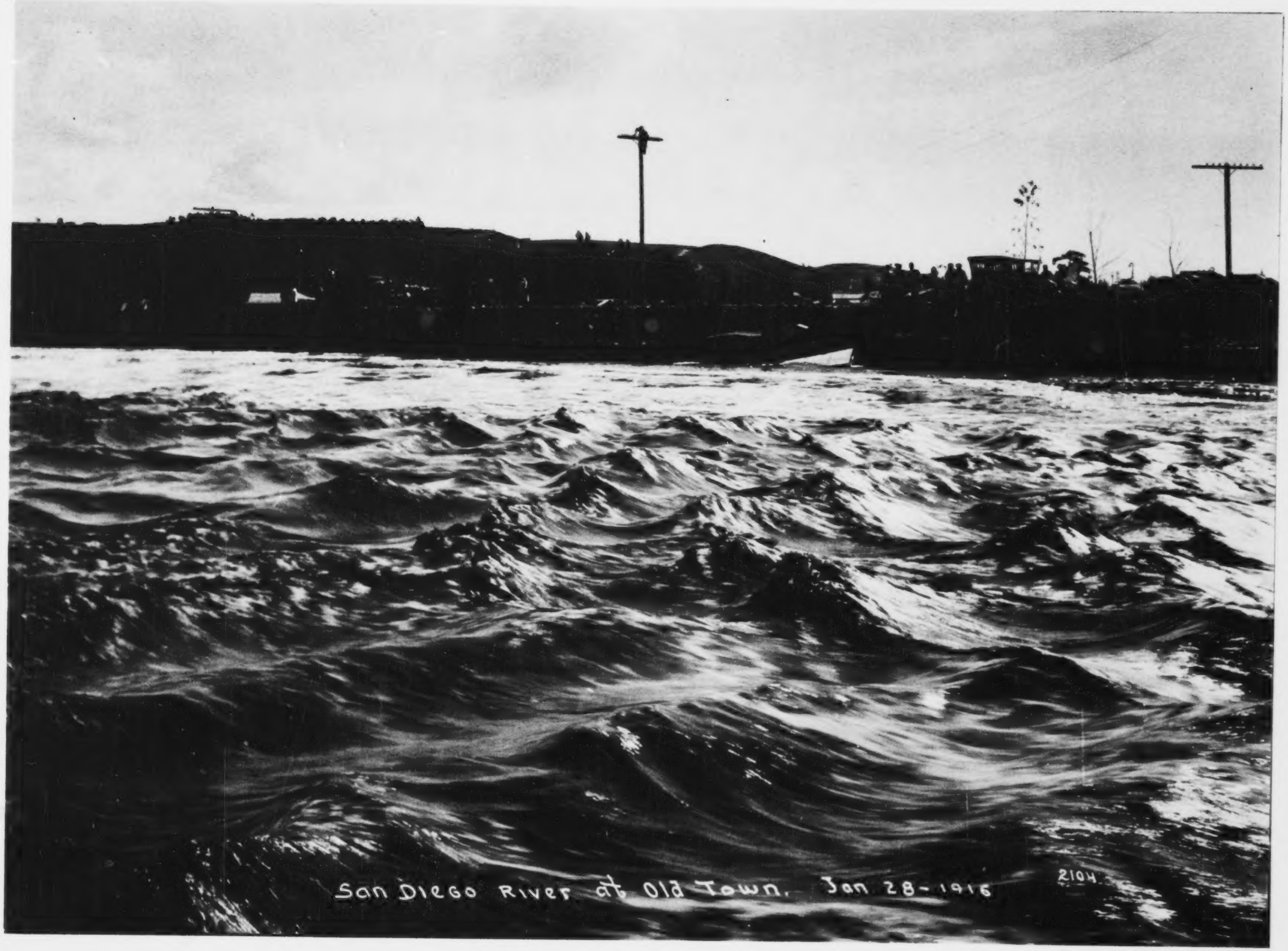
Figure 38

Flooding in Mission Valley during the 1916 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

2072

Figure 39

Photograph of the San Diego River during the 1916 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)



San Diego River at Old Town. Jan 28-1916

2104

Figure 40

San Diego River at the concrete bridge near Old Town during the 1916 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

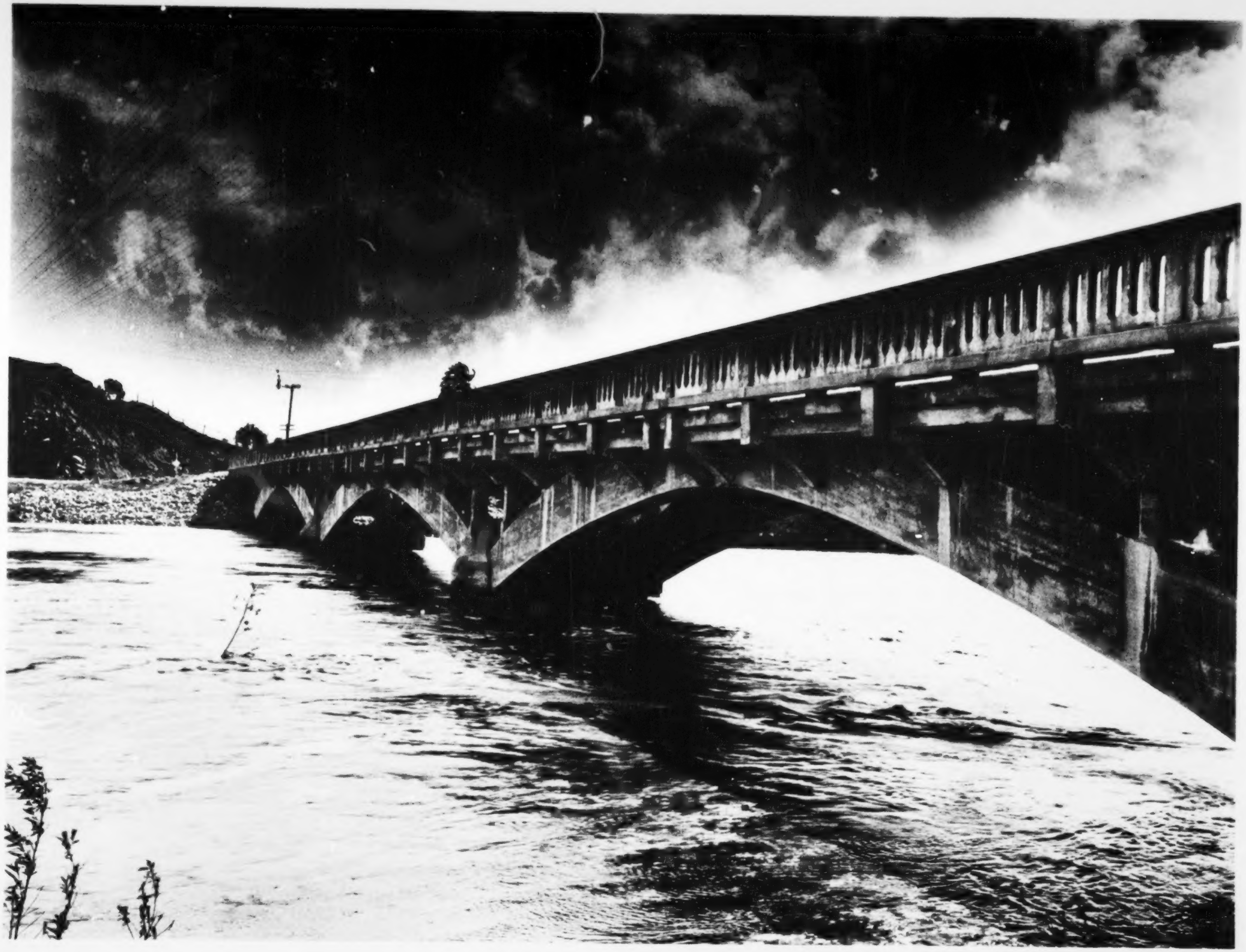
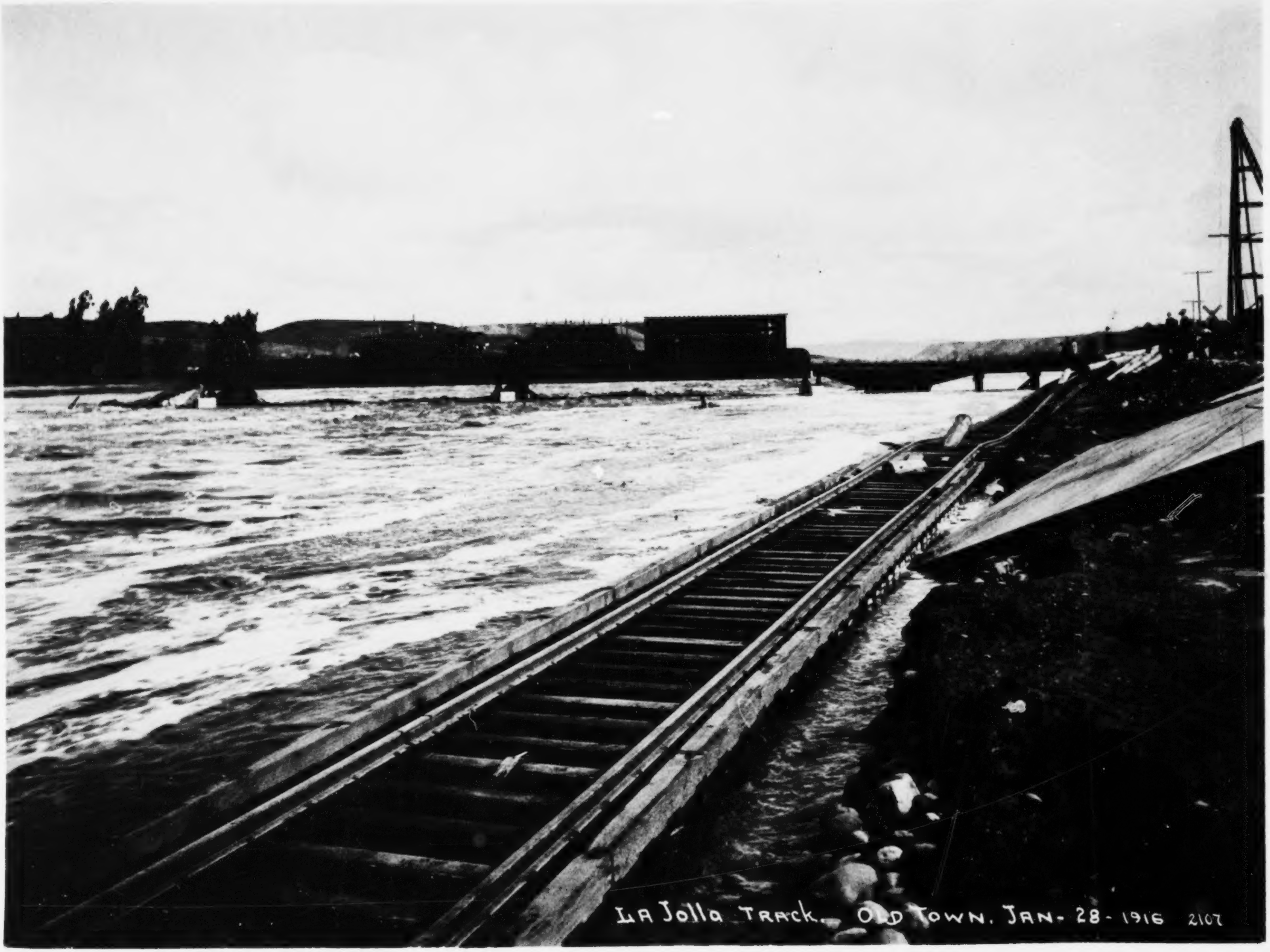


Figure 41

Concrete bridge over San Diego River near Old Town during flood of 1916. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

Figure 42

San Diego River during 1916 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)



La Jolla Track. Old Town. Jan-28-1916 2107

Another significant flood occurred in February 1927 (Figures 43 and 44).

A few years after these major floods San Diegans decided to do something about the threat of flood disaster and the need for water management in the area. As noted previously, construction of El Capitan Dam on the San Diego River was approved in a bond issue in December 1931. The major reservoirs in San Diego County today are described in Table 9. The estimated total peak flood discharges in two assumed reservoir conditions have been computed by the California State Department of Water Resources (1964). These data are given in Table 10. The Department has also derived the average flood hydrograph for San Diego County. This hydrograph,shown in Figure 45,was based on a series of actual hydrographs and the 1916 storm, which lasted 4 days and had an estimated recurrence interval of 100 years.

Figure 43

San Diego River during the 1927 flood. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

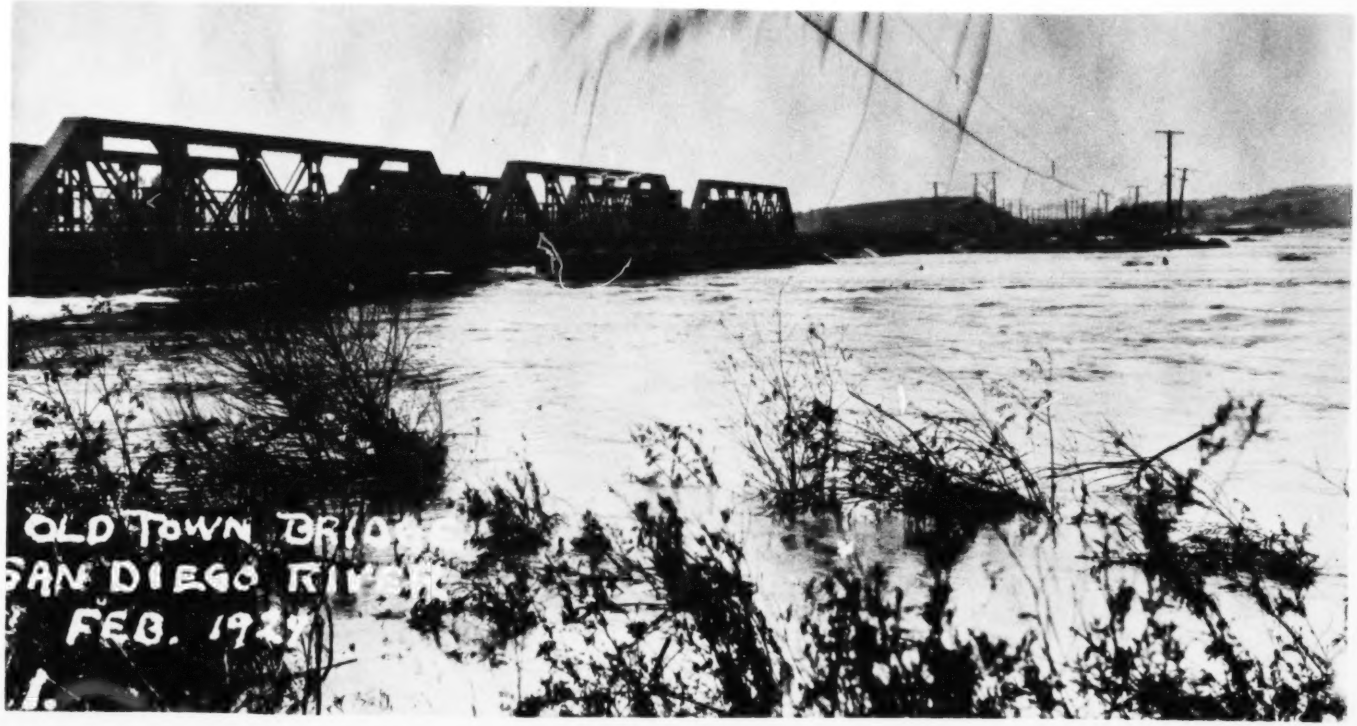

OLD TOWN BRID
SAN DIEGO RI
FEB. 1927

Figure 44

Mission Valley after the flood of 1927. (Historical Collection, Title Insurance and Trust Company, San Diego, California)

TABLE 9

Major Reservoirs in San Diego County Considered in Flood Hazard Investigation

Name of dam	Owner	Stream	Height of dam above original streambed, in feet	Storage capacity, in acre-feet	Area of reservoir*, in acres	Drainage area, in square miles	Use
El Capitan	City of San Diego	San Diego River	217	116,452	1,580	190	Storage of local water for municipal use.
Henshaw	Vista Irrigation Dist.	San Luis Rey River	123	194,323	6,020	205	Storage of local water for irrigation use.
Lake Hodges	City of San Diego	San Dieguito River	131	33,550	1,317	303	Storage of imported and local water for municipal use.
Lake Loveland	California Water & Telephone Company	Sweetwater River	198	27,700	475	98	Storage of local water for municipal, industrial and irrigation use.

TABLE 9 continued

Name of dam	Owner	Stream	Height of dam above original streambed, in feet,	Storage capacity, in acre-feet	Area of reservoir*, in acres	Drainage area, in square miles	Use
San Vicente	City of San Diego	San Vicente Creek	199	90,234	1,069	75	Storage of imported and local water for municipal use.
Savage (Lower Otay Reservoir)	City of San Diego	Otay River	145	56,326	1,132	99	Storage of local and imported water for municipal use.
Sutherland	City of San Diego	Santa Ysabel Creek	162	29,680	550	53	Storage of local water for municipal use.
Sweetwater	California Water & Telephone Company	Sweetwater River	108	27,689	936	182	Storage of local and imported water for municipal, industrial and irrigation use.
Upper Otay	City of San Diego	Proctor Valley Creek	77	2,825	139	13	Storage of local water for domestic and municipal use.

* Area at spillway crest elevation.

From California State Department of Water Resources Bull. 112, Sept. 1964.

TABLE 10

Estimated Total Peak Flood Discharges at Selected Locations in San Diego County

STREAM	LOCATION	Peak discharge in cubic feet per second	
		50-year recurrence interval	100-year recurrence interval
San Diego River	Old Mission Dam	43,000	60,000
	Confluence of San Vicente Creek and San Diego River	36,500	51,000

Assuming Full Reservoir Conditions

STREAM	LOCATION	Peak discharge in cubic feet per second	
		50-year recurrence interval	100-year recurrence interval
San Diego River	Old Mission Dam	18,700	25,500
	Confluence of San Vicente Creek and San Diego River	7,800	10,200

Assuming Partially Full Reservoir Conditions*

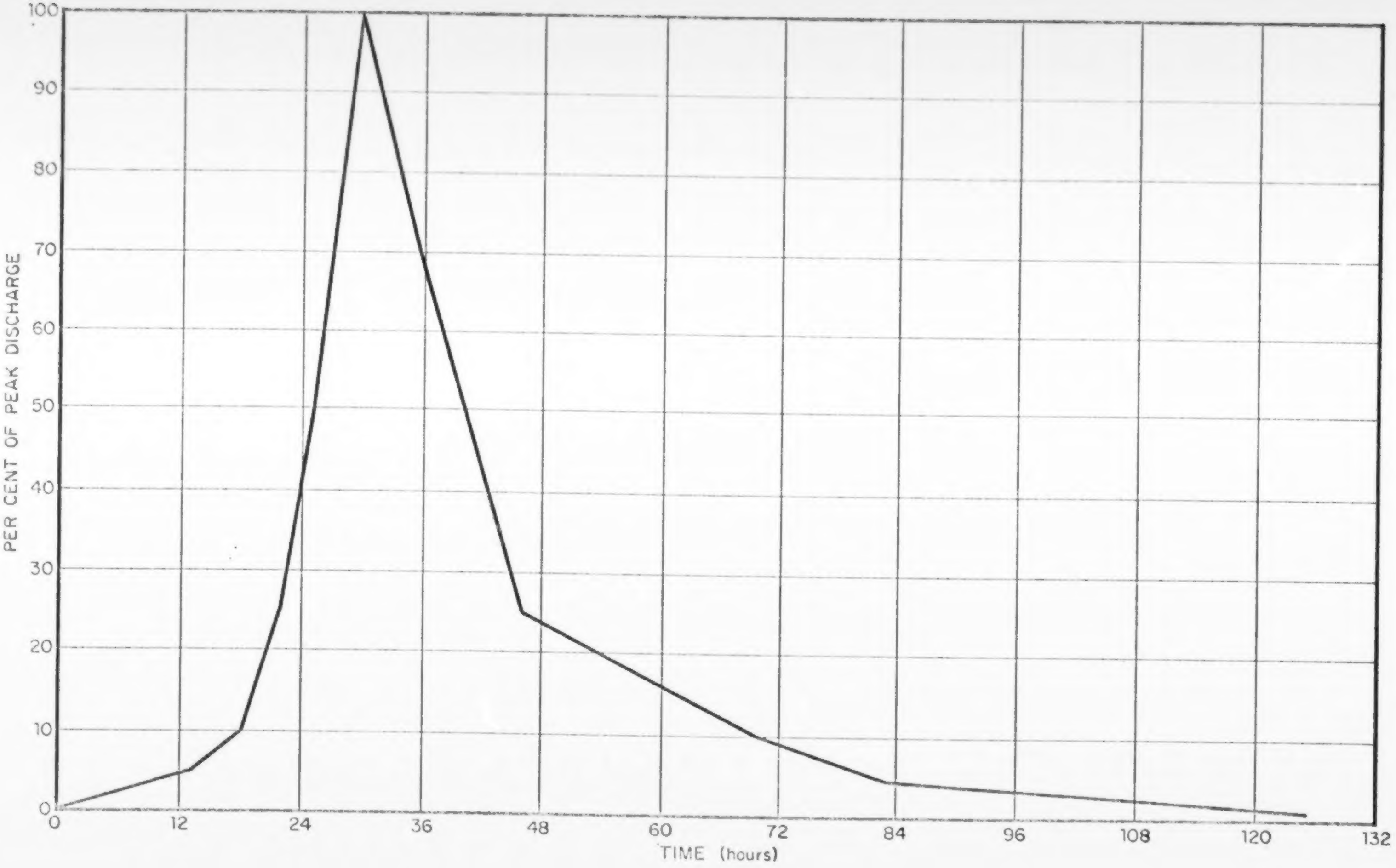
*For the San Diego River System, San Vicente Reservoir was assumed to be two-thirds full and El Capitan Reservoir one-half full at beginning of runoff.

From California State Department of Water Resources Bull. 112, September, 1964.

Figure 45

Average flood hydrograph for San Diego County.
(From California Dept. of Water Resources Bulletin
No. 112.

Note. Since peaking time is different for flows originating in different areas, flood hydrographs are used for fixing the time of peak flows. A series of hydrographs derived from actual storms was analyzed to determine the time at which peak flows occur. The four-day flood of 1916 was used in constructing this average hydrograph because that flood had an approximate recurrence interval of 100 years.


PER CENT OF PEAK DISCHARGE
100
90
80
70
60
50
40
30
20
10
0
0
12
24
36
48
60
72
84
96
108
120
132
TIME (hours)

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OCEANOGRAPHY AND MARINE GEOLOGY OF MISSION BAY

In 1957, the City of San Diego undertook an evaluation of the physical characteristics of Mission Bay Recreation Area which had been proposed in the 1956 Master Plan. A group of consultants headed by Marine Advisers was given the task of collecting, processing and interpreting a large amount of field data pertinent to water characteristics and shoreline planning. Participants in the project included specialists in marine biology and biochemistry, geological oceanography, physical oceanography and meteorology, and hydraulics and coastal engineering. The survey directly involved the local scientific community of San Diego and southern California in the development of this aspect of the estuarine system. The results of the study were prepared for the City of San Diego in a report which contained an evaluation of pertinent oceanographic factors (Marine Advisers, 1957).

The expected significance of Mission Bay Recreation Area to the future community was evident in the 1956 plans. The City's desire to protect the present and proposed investment was expressed in substantive terms when the technical study was undertaken in 1957. The total community was now involved, not only on the basis of the individual's tax dollars, but also on the basis of protecting the individual participating in water contact recreation.

The technical findings in the 1957 study are significant because the total range of hydrographic and physical characteristics of Mission Bay were considered. A brief summary of these findings and recommendations is given here with selected data pertinent to major design parameters.

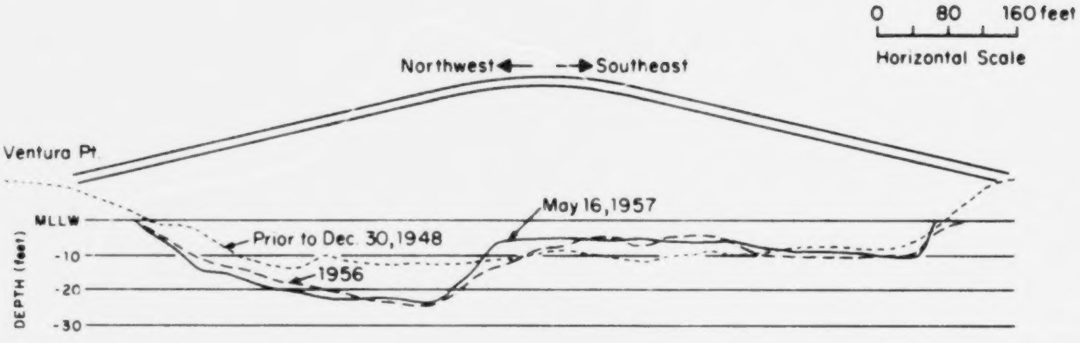
The problem of channel and slope stabilization was recognized. Increasing the tidal prism by dredging would result in erosion of restricted channels in the west part of the Bay. It was pointed out that some of the channel slopes and bottoms at the bridges would have to be stabilized either by protecting the surfaces or by widening the channels; some examples of channels in Mission Bay are plotted in Figure 46 which shows the relation of cross sectional area to tidal prism. Empirical relations suggested by Robins (1931) and O'Brien (1933) are shown on the figure. Changes in bottom depths over a period of 9 years across Ventura Channel at the bridge were shown. There is a suggestion in the data that the Ventura Boulevard channel, for example, was larger in 1957 than would be expected for the tidal prism. This apparent instability may have been related to dredging and improvements along the flood control channel which were completed in 1953. The channels within the Bay were evaluated and ranked in order of potential scour.

It was recognized that the sea breeze regime and general wind pattern in the area (Table 11) would influence the stability of shorelines within the Bay. Proposed shore areas in the east Bay were considered potentially more unstable due to greater exposure to wave erosion than the existing coastline in the west part of the Bay. Wave action can create longshore currents and littoral drift of sediment. This problem existed at the time of the 1957 study. The results of two beach profiles taken at Tierra del Fuego (now Vacation Isle) 10 years apart are shown in Figure 47. The erosion on a west-facing beach

Figure 46

Bottom soundings at Ventura Boulevard Bridge.

Empirical relation between tidal prism and channel area. (From Marine Advisers, Inc., 1957)


0
80
160 feet
Horizontal Scale
Northwest
Southeast
Ventura Pt.
May 16, 1957
Prior to Dec. 30, 1948
1956
MLLW
-10
-20
-30
DEPTH (feet)

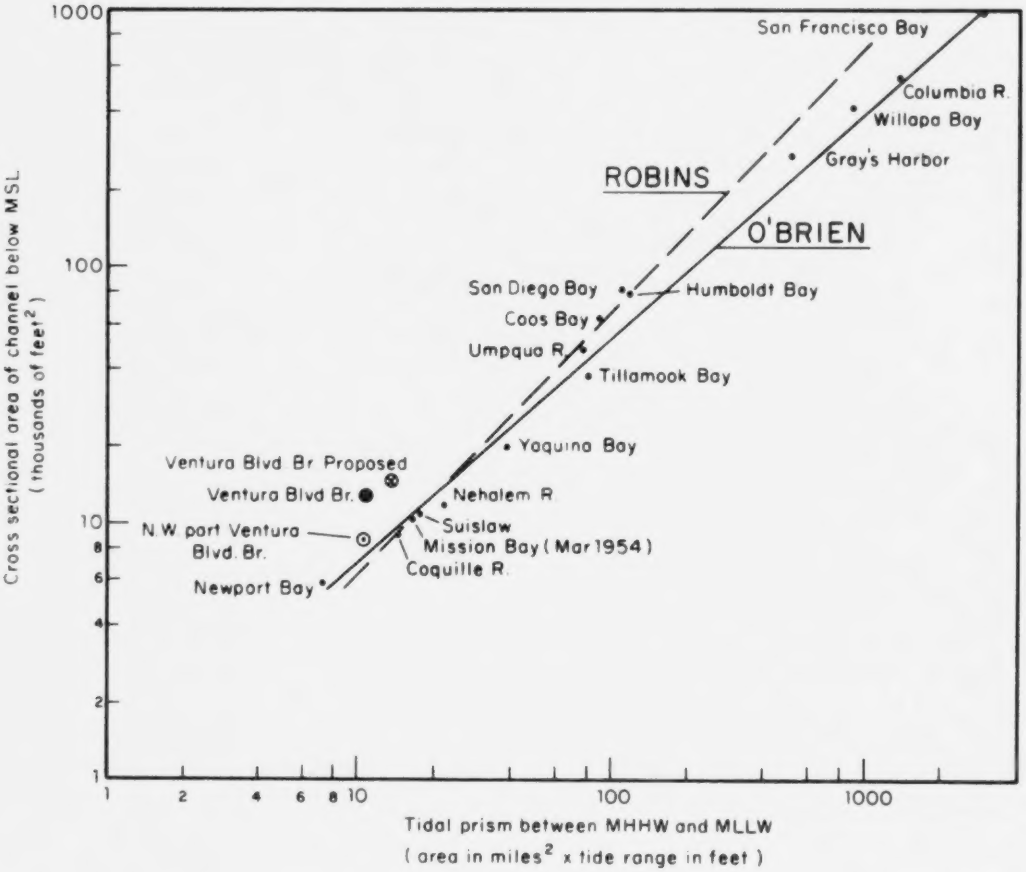

1000
100
10
8
6
4
2
1
Cross sectional area of channel below MSL
(thousands of feet^2)
1
2
4
6
8
10
100
1000
Tidal prism between MHHW and MLLW
(area in miles^2 x tide range in feet)
San Francisco Bay
Columbia R.
Willapa Bay
Gray's Harbor
ROBINS
O'BRIEN
San Diego Bay
Humboldt Bay
Coos Bay
Umpqua R.
Tillamook Bay
Yaquina Bay
Ventura Blvd Br. Proposed
Ventura Blvd Br.
Nehalem R.
N.W. part Ventura Blvd. Br.
Suislaw
Mission Bay (Mar 1954)
Coquille R.
Newport Bay

TABLE 11

Annual average frequencies (in percent) of wind direction and speed at Lindbergh Field, San Diego, California

Speed (mi. /hr.) Period: 9/49 - 8/54

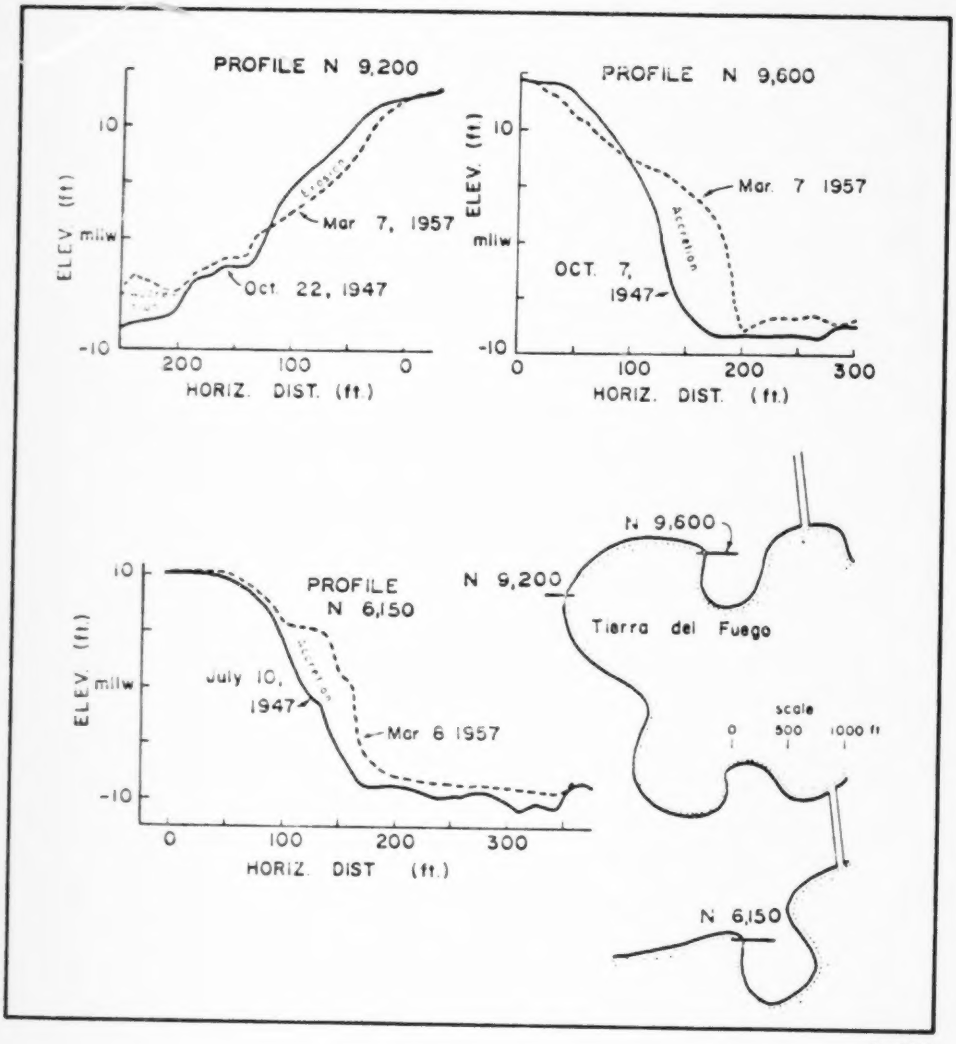
Direction	0-3	4-7	8-12	13-18	19-24	25-31	32-38
N	5	4	x	x			
NNE	3	3	x	x			
NE	4	3	x	x	x		
ENE	1	1	x	x	x		
E	2	1	x	x			
ESE	1	1	x	x		x	
SE	1	1	x	x	x	x	
SSE	x	1	1	x	x	x	x
S	1	3	2	1	x	x	
SSW	1	3	3	x	x	x	x
SW	1	4	3	x	x		
WSW	1	3	3	x	x	x	
W	1	4	4	1	x	x	
WNW	x	4	6	1	x	x	
NW	1	4	3	x	x	x	
NNW	1	3	1	x	x		
Calm	3						

x - indicates more than 0 but less than 0.5

From Marine Advisers, Inc. report prepared for the City of San Diego 25 July 1957.

Figure 47

Example of profiles of eroding and accreting beaches. (From Marine Advisers, Inc., 1957)


PROFILE N 9,200
10
ELEV. (ft) mllw
-10
200
100
0
HORIZ. DIST. (ft.)
Erosion
Mar 7, 1957
Oct. 22, 1947
PROFILE N 9,600
10
ELEV. (ft) mllw
-10
0
100
200
300
HORIZ. DIST. (ft.)
Mar. 7 1957
Accretion
OCT. 7, 1947
PROFILE N 6,150
10
ELEV. (ft.) mllw
-10
0
100
200
300
HORIZ. DIST (ft.)
July 10, 1947
Accretion
Mar 6 1957
N 9,600
N 9,200
Tierra del Fuego
scale
0
500
1000 ft
N 6,150

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and the accretion on the eastern extremity of the same beach zone are clearly shown. Longshore currents which could potentially be generated in the Bay were computed (See Figure 48). The expected erosion and accretion areas were defined for future maintenance planning.

Actual measurements of longshore currents were made at three locations on the Tierra del Fuego beach where the sand drift had been documented. The locations are shown in Figure 52, and the results are given in Table 12.

Small waves in the Bay can produce a sharp change in slope at about minus one foot MLLW, a depth that can be hazardous to children. It was recommended that beaches be constructed on a stable slope angle even in areas where longshore transport was not expected. It was desirable to avoid exposure of underlying marsh deposits which were considered undesirable for bathers.

Bottom sediments were sampled in most of the Bay. The distribution of bottom sediments in 1957 is shown in Figure 49. Sands were found primarily in the channels. The coarser sand was in the lower Bay and near the entrance. The location of core samples taken by Marine Advisers and the U. S. Army Corps of Engineers is shown in Figure 50. The general classification of some of these core samples is given in Table 13.

The tidal current regime in the Bay was studied in order to evaluate the potentially turbid areas and to compare the sediment distribution and current patterns. The flow net of water areas shown in Figure 51 was used

Figure 48

Computed longshore currents and areas of erosion and accretion due to waves from a wind equivalent to the resultant of all winds stronger than 9 miles per hour. (occurrence 29% of the time). (From Marine Advisers, Inc., 1957)

KEY

······ = Computed erosion areas.

—— = Computed accretion areas.

2.8 → = Current speed (ft/sec) and direction.

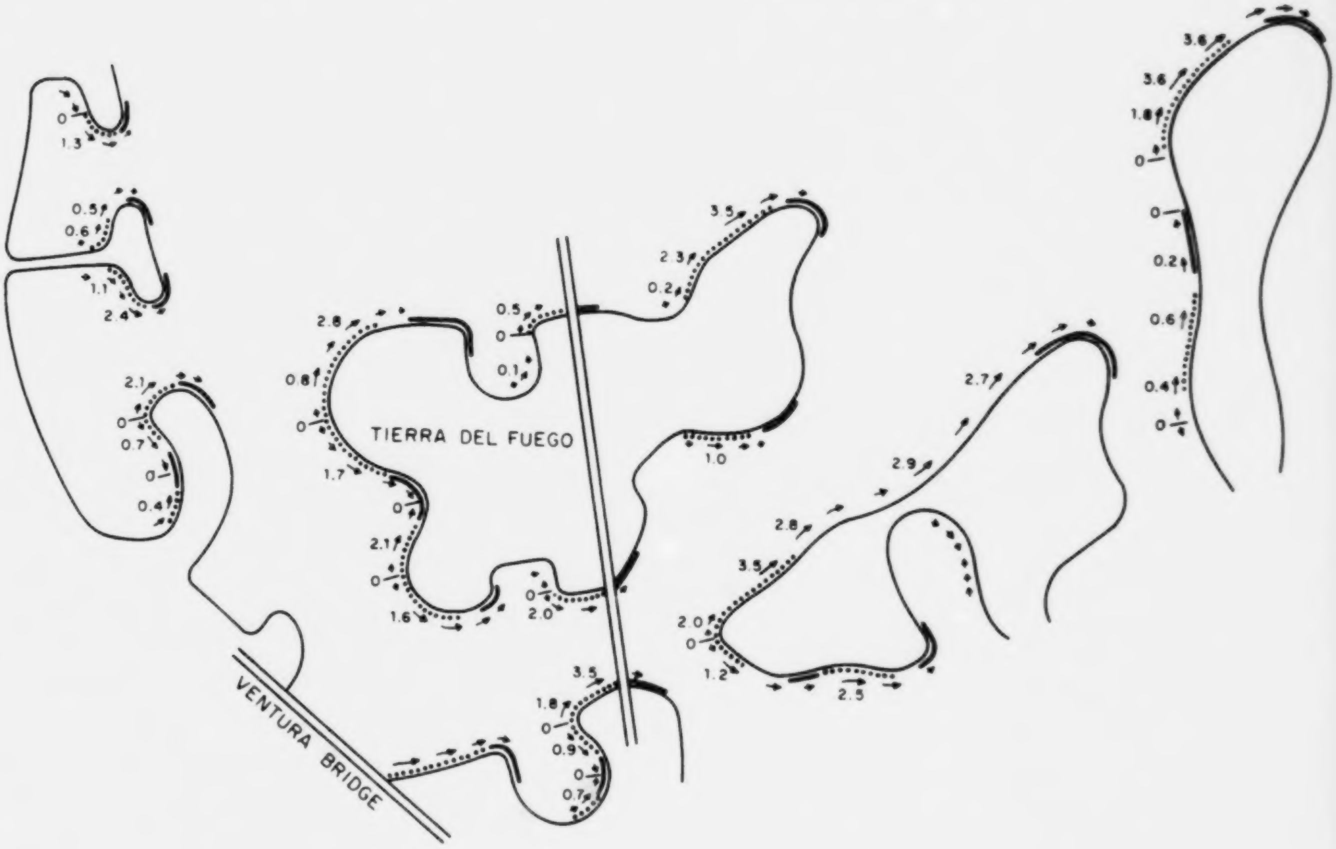
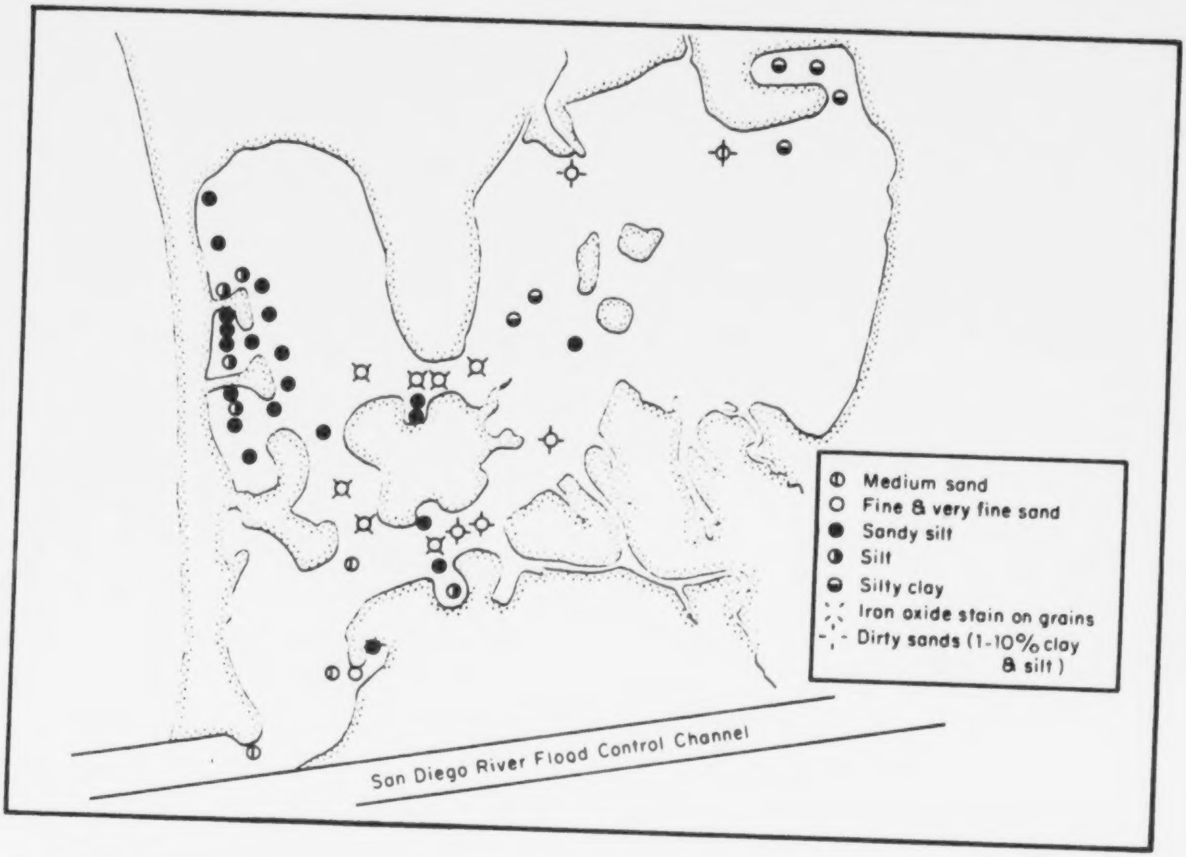

TIERRA DEL FUEGO
VENTURA BRIDGE
0
1.3
0.5
0.6
1.1
2.4
2.1
0
0.7
0
0.4
2.8
0.8
0
1.7
0
2.1
0
1.6
0.5
0
0.1
0
2.0
3.5
2.3
0.2
1.0
3.5
1.8
0
0.9
0
0.7
2.7
2.9
2.8
3.5
2.0
0
1.2
2.5
3.6
3.6
1.8
0
0
0.2
0.6
0.4
0

Figure 49

Bottom sediment types in Mission Bay.

Figure 50

Location of cores in Mission Bay taken by the Corps of Engineers and Marine Advisers. (From Marine Advisers, Inc., 1957)


◐ Medium sand
○ Fine & very fine sand
● Sandy silt
◑ Silt
⊖ Silty clay
Iron oxide stain on grains
Dirty sands (1-10% clay & silt)
San Diego River Flood Control Channel

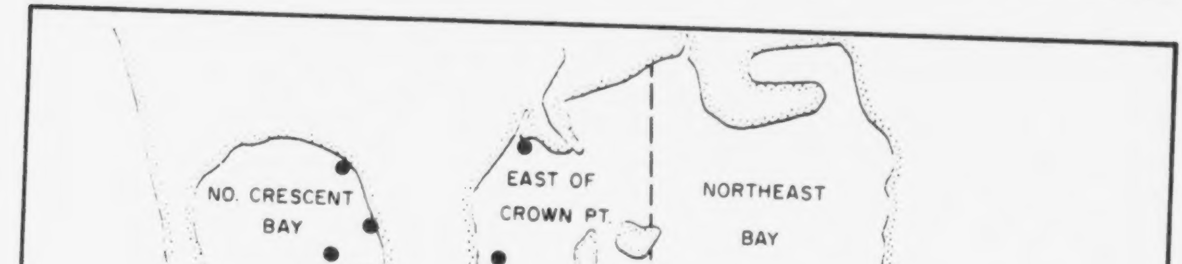
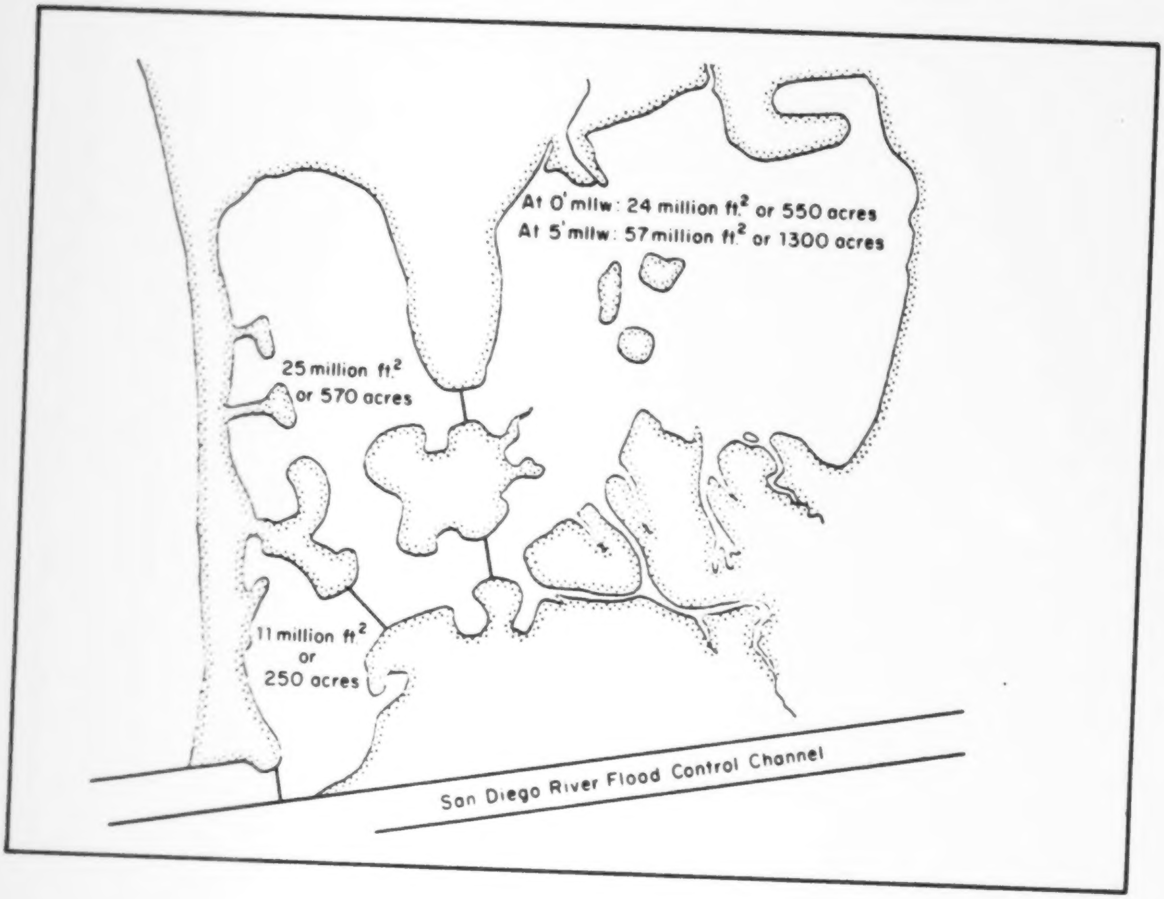

NO. CRESCENT BAY
SO. CRESCENT BAY
EAST OF CROWN PT.
NORTHEAST BAY
EAST BAY
SOUTHEAST BAY
QUIVIRA BASIN
San Diego River Flood Control Channel

Figure 51

Approximate water areas in Mission Bay.

Figure 52

Positions of longshore current measurements in Mission Bay, May 28, 1957. (From Marine Advisers, Inc., 1957)


At 0' mllw: 24 million ft.^{2} or 550 acres
At 5' mllw: 57 million ft.^{2} or 1300 acres
25 million ft.^{2}
or 570 acres
11 million ft.^{2}
or
250 acres
San Diego River Flood Control Channel

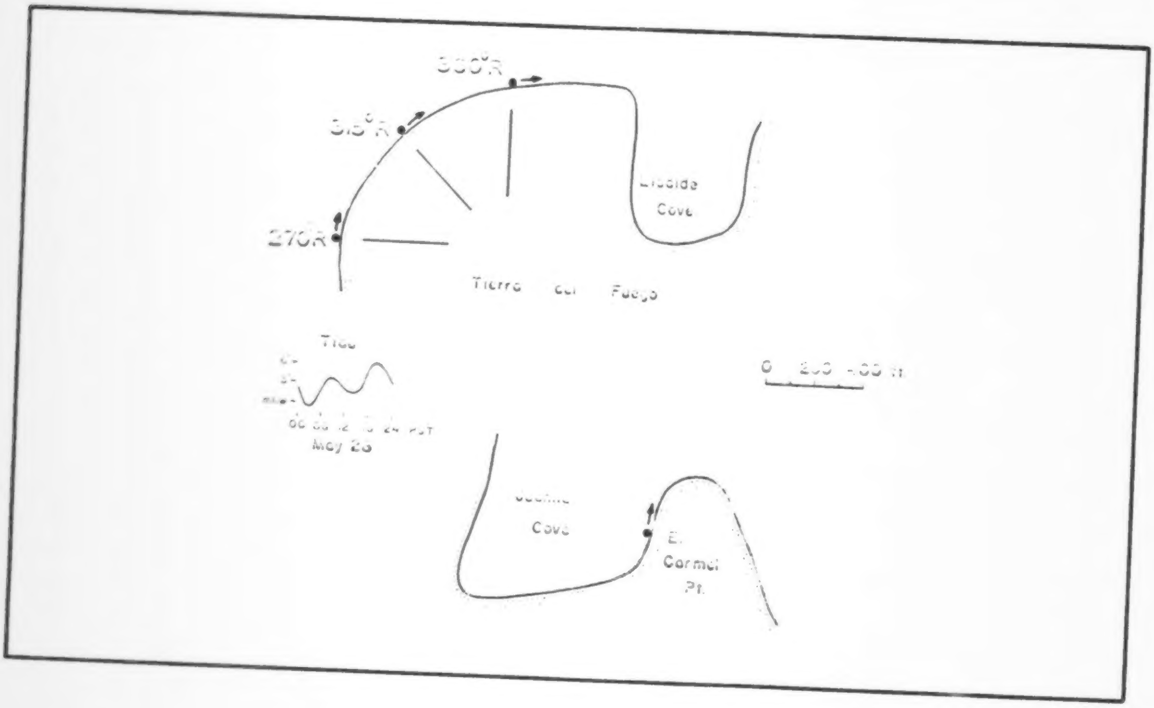

360°R
315°R
270R
Lisside
Cove
Tierra del Fuego
Tide
6'
3'
mllw
00 06 12 18 24 PST
May 28
0 200 400 ft
Cove
El
Carmel
Pt.

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TABLE 12

Longshore current[1] measurements in Mission Bay, California, May 28, 1957

Position[2]	Time PST	Height of breaking waves	Observed current speed (ft/sec)	Dir. of drift	Breaking wave angle with shore
Tierra del Fuego					
270R	0955	0.5 -1.0 in. est.	0.29	N	20°
	1014	0.5 -1.0 in. est.	0.25	N	-
	1039	0.5 -1.0 in. est.	0.14	N	10°
	1058	1.0 -1.5 in. est.	0.12	N	-
	1130	1.0 -1.5 in. est.	0.10	N	-
	1227	1.5 in. est.	0.06	N	5°
	1305	1.5 -2.0 in. est.	0.17	N	-
	1400	1.5 -2.0 in. est.	0.09	N	-
315R	1400	0.10 ft. meas.	0.83	NE	40 - 50°
	1415	0.14 ft. meas.	0.83	NE	"
	1515	-	0.83	NE	"
360R	1005	0.5 -1.0 in. est.	0.30	E	65 - 70°
	1024	0.5 -1.0 in. est.	0.65	E	"
	1049	0.5 -1.0 in. est.	0.62	E	"
	1121	1.0 -1.5 in. est.	0.55	E	"
	1213	1.5 in. est.	0.52	E	"
	1245	1.5 in. est.	0.80	E	"
	1337	1.5 in. est.	0.61	E	"
	1408	1.5 in. est.	0.61	E	"
El Carmel Point					
Note 3	1340 - 1520	.096 ft. meas.	0.35	N	15 - 20°

1. Measurements made between water line and breaking wind chop.
2. See Figure.
3. Results are average of 9 readings.

From Marine Advisers, Inc. report prepared for the City of San Diego, 25 July 1957.

TABLE 13

Log of Marine Advisers' cores from Mission Bay

Core No.	File No.	North Coord.	West Coord.	Approx. Ground Elev.	Approx. Bottom Elev.	General Classification
2	5704C-44	6000	10700	6	-6	Sandy silt
3	5704C-45	5100	10500	7.5	-4.5	Sandy silt
7	5705C-49	4900	16000	6.0	-4.0	Silty sand
8	5705C-50	6500	9000	9.0	-1.0	Silty sand
10	5705C-51	11800	12300	3.0	-13.0	Silty sand
11	5705C-52	9800	11800	4.0	-16.0	Sandy silt
12	5705C-53	8200	12900	5.0	-11.0	Sandy silt
13	5705C-54	9700	10300	4.0	-14.0	Silty sand
14	5705C-55	9500	7900	3.0	-11.0	Silty sand
15	5705C-56	7200	11800	5.0	-10.0	Silty sand
16	5705C-57	6900	14000	3.0	-12.0	Silty sand
17	5705C-58	6300	11600	7.0	-5.0	Silty sand
19	5705C-60	10200	16400	2.0	-13.0	Silty sand
20	5705C-61	12500	14300	1.0	-17.0	Silty sand
21	5705C-62	14100	13800	1.0	-14.0	Silty sand
22	5705C-63	6900	9700	7.0	-11.0	Sandy clayey silt
23	5705C-64	7800	10200	6.0	-9.0	Sandy clayey silt
24	5705C-65	6800	10700	6.0	-2.0	Sandy clayey silt
26	5705C-67	6200	9300	6.0	-6.0	Sandy clayey silt
27	5705C-68	8000	8800	7.0	-5.0	Sandy clayey silt
28	5705C-69	12800	16900	1.0	-14.0	Silty sand
29	5705C-70	14200	17500	1.0	-14.0	Silty sand
30	5705C-71	12400	17600	0	-15.0	Silty sand
31	5705C-72	11700	18400	0	-9.0	Silty sand
32	5705C-73	10800	18000	2.0	-10.0	Silty sand

TABLE 14

Inorganic suspended material content of water samples from Mission Bay

Water Sample No.	Dry weight of solids	Inorganic content (Ash weight of solids)	Inorganic portion of total solids (Dry weight)
1	18.8 mg/l	4.1 mg/l	22%
2	5.1	1.4	28
3	7.7	6.3	82
4	20.4	16.1	79
5	-	6.1	-
6	17.2	9.4	55
7	17.4	9.1	52
8	38.0	25.4	67

From Marine Advisers, Inc. report prepared for the City of San Diego, 25 July 1957.

as a basis for estimating maximum ebb current speeds expected in various channels. These results are given in Table 15 for four locations on the Bay. The mean of the observed values differed from the mean of the computed speeds by less than 20 percent. A comparison of observed currents and those calculated on the basis of tidal prism is shown in Table 16.

Spoil from proposed dredging areas was ranked in order of its desirability for re-use. The basis for such an evaluation can be seen in the sediment grain size distributions in Figure 53. The median grain sizes shown here range from coarse silt in the shallow East Bay to fine sand in Quivira Basin. Clean, coarse sand suitable for beach facing was not found in adequate quantities for dredge removal. The report stressed the importance of a more thorough investigation into the character and extent of potential dredge material and detailed scheduling of spoil deposition before any dredging program was to commence. The general level of concentration of inorganic suspended material in Mission Bay water in 1957 is given in Table 14.

It was the opinion of the investigators that the water characteristics, such as transparency, odor and color, would be improved over the entire Bay by dredging the east part of the Bay. It was noted that the east part of the Bay would always be more turbid than the west portion. The results of some of the investigations relating water characteristics to tidal action in the Bay are shown in Figures 54 through 56.

Potential wave action and surging problems were anticipated in the 1957 report. It was concluded that dredging of the channel between Ventura

Figure 53

Grain-size distribution of sediments in Mission Bay.
(From Marine Advisers, Inc., 1957)

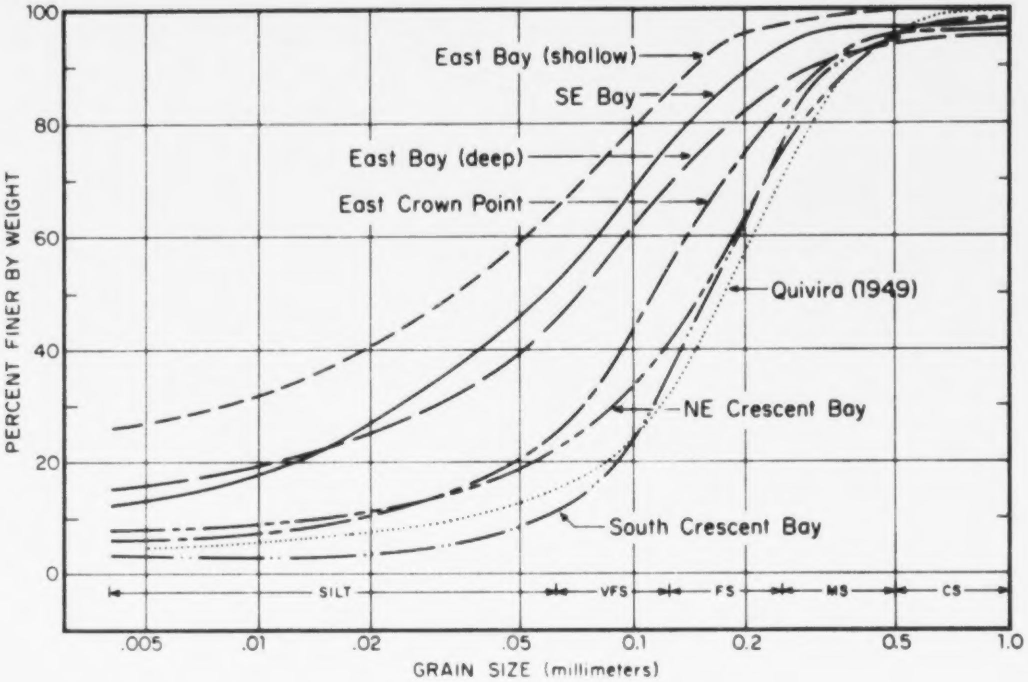


Table 15 Maximum ebb current speed observed and calculated by the flow net method. Values are in ft. /sec.

Date	Feb. 27, 1957		Mar. 14, 1957		Apr. 27, 1957	
Location	Observed	Computed	Observed	Computed	Observed	Computed
Entrance Channel	1.32	2.61	3.35	2.91	1.55	1.35
Ventura Blvd. Bridge	—	—	—	—	1.88	2.46
N. Causeway Bridge	—	—	1.35	1.31	0.73	0.56
S. Causeway Bridge	1.22	2.19	1.64	2.65	1.69	1.13

Average all locations, all dates:

Observed 1.65 ft. /sec.
Computed 1.93 ft. /sec.

TABLE 16

Maximum ebb current speed at the Bay entrance observed and calculated from tidal prism

Date	Tide Range	Observed	Calculated
Feb. 27, 1957	6.0 ft.	1.32 ft./sec.	2.34 ft./sec.
Mar. 14, "	6.9 "	3.35 "	2.68 "
Apr. 27, "	3.3 "	1.55 "	1.29 "

From Marine Advisers, Inc. report prepared for the City of San Diego, 25 July 1957.

Figure 54

Vertical variation of light intensity in Mission Bay.
(From Marine Advisers, Inc., 1957)

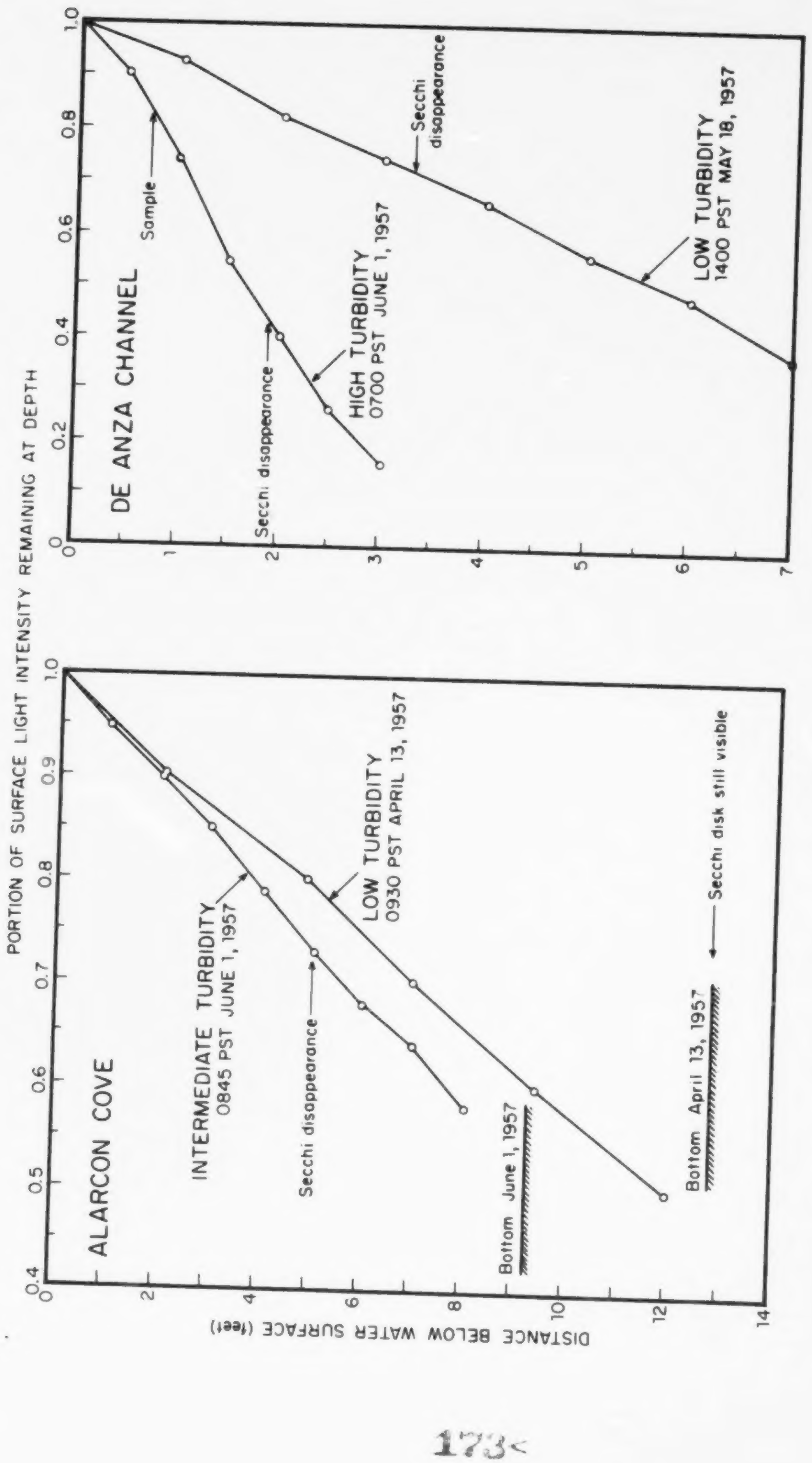
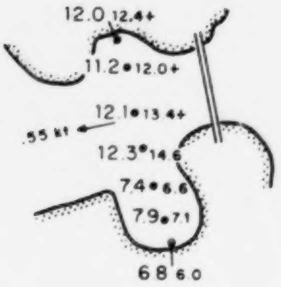

ALARCON COVE
INTERMEDIATE TURBIDITY
0845 PST JUNE 1, 1957
LOW TURBIDITY
0930 PST APRIL 13, 1957
Secchi disappearance
Bottom June 1, 1957
Bottom April 13, 1957
Secchi disk still visible
DE ANZA CHANNEL
Sample
Secchi disappearance
HIGH TURBIDITY
0700 PST JUNE 1, 1957
Secchi disappearance
LOW TURBIDITY
1400 PST MAY 18, 1957
PORTION OF SURFACE LIGHT INTENSITY REMAINING AT DEPTH
DISTANCE BELOW WATER SURFACE (feet)
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
14
0
1
2
3
4
5
6
7

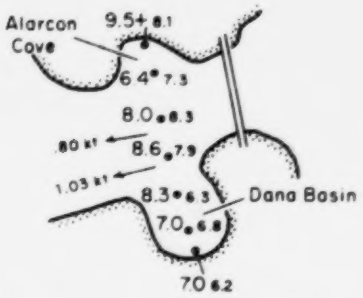
Figure 55

Changes in water transparency readings in Mission Bay between Alarcon Cove and Dana Basin during ebb tide current, April 13, 1957. (From Marine Advisers, Inc., 1957)

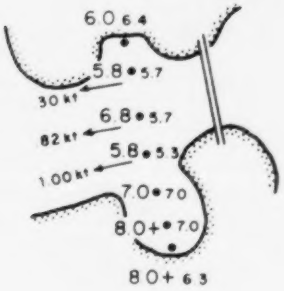
0920 - 0943 PST


12.0 12.4+
11.2 12.0+
12.1 13.4+
.55 kt
12.3 14.6
7.4 6.6
7.9 7.1
6.8 6.0

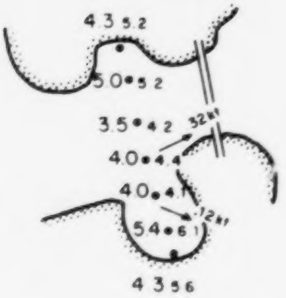
1052-1134 PST


Alarcon Cove
9.5+ 8.1
6.4 7.3
8.0 8.3
.80 kt
8.6 7.9
1.03 kt
8.3 6.3
Dana Basin
7.0 6.8
7.0 6.2

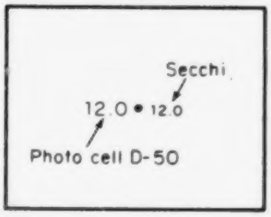
1152-1233 PST


6.0 6.4
5.8 5.7
30 kt
6.8 5.7
82 kt
5.8 5.3
1.00 kt
7.0 7.0
8.0+ 7.0
8.0+ 6.3

1458-1534 PST


4.3 5.2
5.0 5.2
3.5 4.2
32 kt
4.0 4.4
4.0 4.1
.12 kt
5.4 6.1
4.3 5.6

KEY


Secchi
12.0 12.0
Photo cell D-50

TIDE CURVE

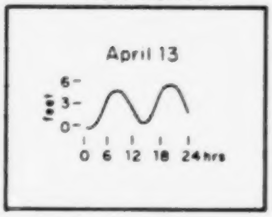


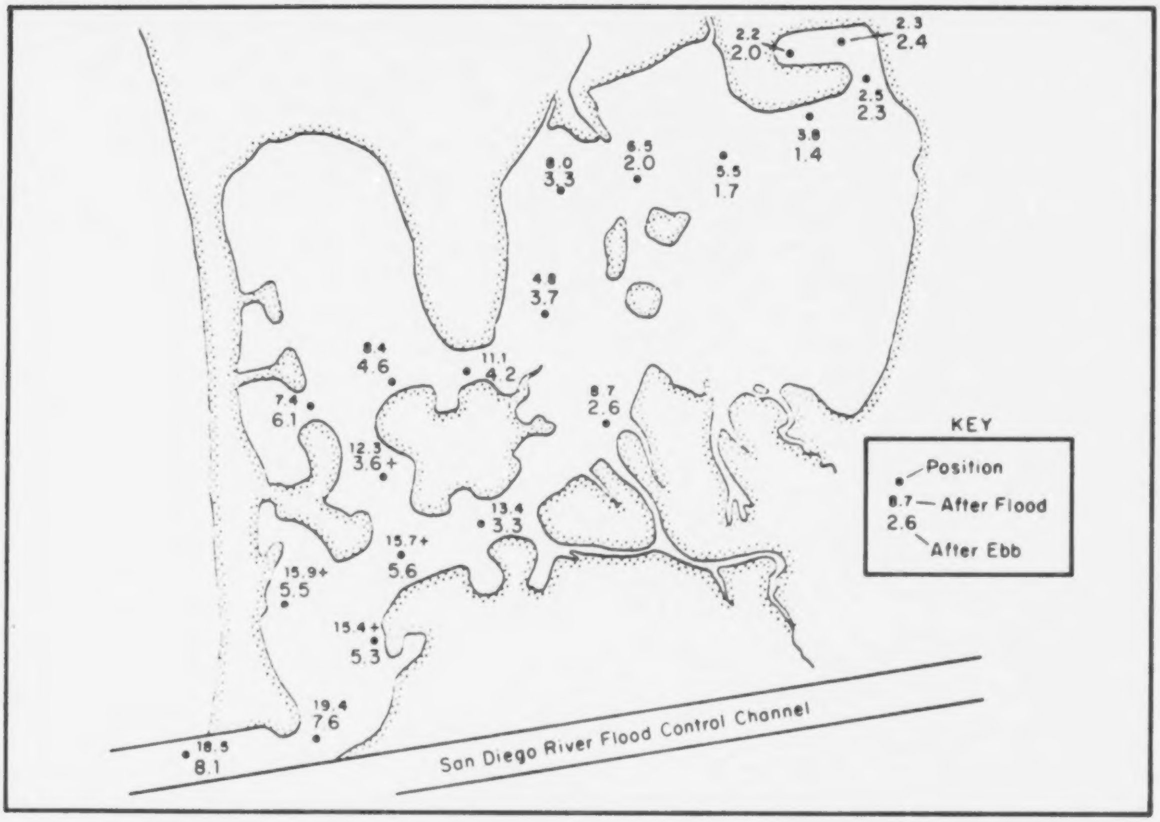
Figure 56

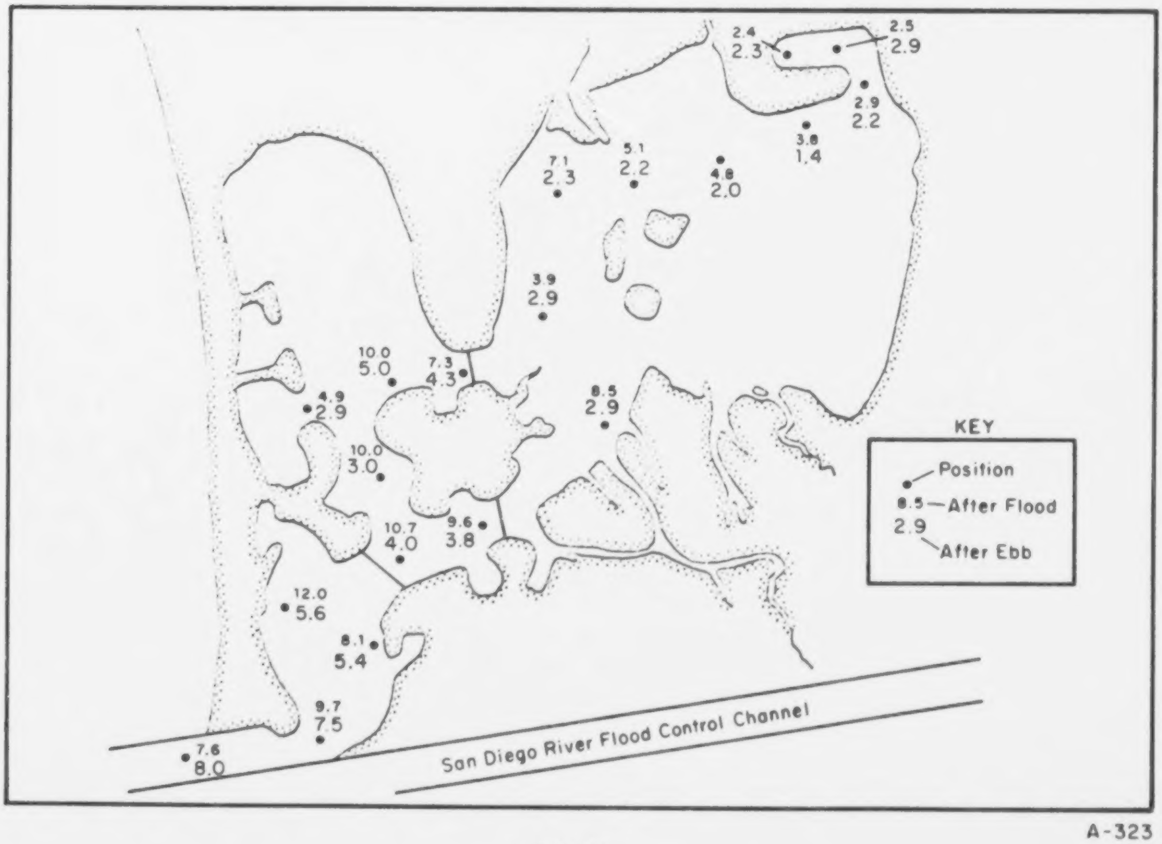
Secchi disk readings after flood and ebb current, April 13, 1957.

Photocell D-50 readings after flood and ebb current, April 13, 1957. (From Marine Advisers, Inc., 1957)

Note. 1. Values in feet.

2. D-50 means that a reading 50 percent of the surface value was obtained at a depth of x feet.


2.2
2.0
2.3
2.4
2.5
2.3
3.8
1.4
8.0
3.3
6.5
2.0
5.5
1.7
4.8
3.7
8.4
4.6
11.1
4.2
7.4
6.1
8.7
2.6
12.3
3.6+
13.4
3.3
15.7+
5.6
15.9+
5.5
15.4+
5.3
19.4
7.6
18.5
8.1
San Diego River Flood Control Channel
KEY
Position
8.7 After Flood
2.6 After Ebb


2.4
2.3
2.5
2.9
2.9
2.2
3.8
1.4
7.1
2.3
5.1
2.2
4.8
2.0
3.9
2.9
10.0
5.0
7.3
4.3
4.9
2.9
8.5
2.9
10.0
3.0
10.7
4.0
9.6
3.8
12.0
5.6
8.1
5.4
9.7
7.5
7.6
8.0
San Diego River Flood Control Channel
KEY
Position
8.5 After Flood
2.9 After Ebb

Boulevard Bridge and the Bay entrance would increase wave and surge activity in and around Quivira Basin. Sloping beaches to dampen the activity and changes in the entrances to Quivira Basin and the Bay were cited as possible remedies. Surging was expected in the proposed Glenn Rick Bay. Damaging surges were not expected anywhere inside Ventura Boulevard Bridge from normal wave activity.

It was concluded that dredging of the Bay to minus eight feet MLLW would not alter the habitat for marine life. Eel grass was to be controlled during its non-growth season, June - October, by mechanical removal during June. The fish species commonly caught in Mission Bay are shown in Table 17.

It was recommended by the study group that a definite policy be formulated for the development of Mission Bay and that it should be founded on the need for satisfaction of both functional use and technical (engineering and hydrographic) design requirements. Two alternative courses of action were cited. The first was the approval of the 1956 Master Plan with the beach construction and shore protection measures developed by the study. The second alternative was to endorse the use of a more regular and hydrodynamically correct shoreline which would cost less to construct and be more economical to maintain. It was noted that a redesign would necessitate a new analysis of functional use data so that space requirements within the Bay could be met satisfactorily. It was urged that continued studies be made of the Bay to compile more complete engineering and hydrographic data. This was to be utilized along with the functional use information in further Mission Bay development.

TABLE 17

Number of fish by species taken during 5739 fishing hours in the 1950 - 51 Mission Bay survey

Species	Number	Per Cent of total
Spotfin Croaker	129	11.2
Yellowfin Croaker	25	2.2
California Halibut	74	6.4
Diamond Turbot	118	10.2
Kelp and Sand Bass	109	9.5
Spotted Bass	30	2.6
Surfperches	481	41.8
Round Stingray	61	5.3
Other Rays and Sharks	60	5.2
White Sea Bass	4	.3
California Corbina	3	.3
All other	56	4.9
Total	1150	99.9

From Marine Advisers, Inc. report prepared for the City of San Diego, 25 July 1957.

Other more specific recommendations are given below.

Tides and Tidal Currents

1. To assure adequate piling penetration at the South Causeway, it was recommended that the entire channel cross section including bottom be stabilized with rock or concrete. During and after the City's dredging program, frequent soundings to assure adequate piling penetration were recommended along the northwest part of Ventura Boulevard Bridge and along the North Causeway Bridge until the bottom profiles become stable.

2. Revetment was suggested for about 500 to 600 feet northward from the bridge along the east side of Ventura Point. It was understood that all shoreline in the proposed Mission Harbor was to be revetted between the Bay entrance and Ventura Boulevard Bridge with fairly heavy stone.

3. It was recommended that all unnecessary restrictions in the tidal flow pattern and abrupt changes in tidal flow direction, such as were evident around Tierra del Fuego or the proposed Cabrillo Point, be avoided in future Bay development. Addition of shore protection instead of changes in shoreline configuration was suggested in instances where the shoreline was already in place.

Waves and Longshore Transport

1. Artificial obstructions designed to shelter shore areas from erosion by small wind waves could not be considered effective if the obstructions were to be more distant than 500 to 1000 feet.

2. Promontories and coves facing westerly directions were to be constructed in the shape of a cycloid instead of an arc of a circle, which had been used in the west part of the Bay. Longer stretches of westerly-facing shoreline were to be straight or gently undulating. It was anticipated that revetment would be necessary for sharp promontories exposed directly to prevailing wave action.

3. Where practical, the east sides of land area, such as Crown Point, were to be utilized for beaches in preference to more exposed areas.

4. Routine speed boat racing and water ski activity was to be restricted to at least 1000 feet from sand beaches where it was desired to keep erosion minimal.

5. Corrective measures recommended for eroded areas in the west part of the Bay included the planned clean-up dredging of the channel and cove entrances around Tierra del Fuego and the reshaping, resurfacing and use of shore protection measures on northwest and southwest Tierra del Fuego.

Shoreline Slope and Configuration

1. Shoreline exposed to considerable wave and/or tidal action was to be constructed from the most stable sediment available. This was to be the coarsest and best-sorted sediment.

2. Exposed points and shore irregularities which are exposed to waves were to be built on as large a radius as practical where riprap, bulkheads, or groins were not desirable. The cycloidal shape suggested previously presents a relatively small curvature exposed for a promontory of a given size and best fulfills the recommendation for a small promontory.

3. It was suggested that large coves not have small entrances.

4. Development of equipment and techniques for eel grass control on bathing beach slopes was needed.

5. Groins, riprap or revetment were called for where considerable beach erosion was expected. This was to prevent littoral transport which results in alteration of the original shoreline, silting of coves and channels, loss of beach sand and increased maintenance problems.

6. Loosening of beach sand within the tidal range by mechanical cleaning equipment should be curtailed unless compaction by rolling or other means was accomplished immediately following the cleaning operation.

7. A table of beach slopes recommended for various parts of the Bay was given.

Dredging and Spoil Deposition

1. As soon as practicable after hydraulic filling of a diked enclosure has been completed, a dredge cut to project depth should be made along those segments of the dike that are to front on the water in order to avoid loss of sand by wave erosion.

2. Careful budgeting of dredged spoil so as to accomplish conservation of clean sands for diking and beach construction is of utmost importance.

3. Additional coring and sediment analysis should be done before scheduling the dredging in Mission Bay; washing of samples must be avoided, and the settling-rate technique for sample analysis is recommended.

4. Because this study showed larger percentages of very fine sediments than previously known in the Bay, it was recommended that additional study be made to optimize the disposal of "poorer than poor fill" material resulting from dredging fine sediments.

Water Characteristics

1. It was recommended that storm drains and streams be prevented from emptying directly into coves. They should enter the Bay downwind from cove entrances. The feasibility of removal of existing storm drains in coves should be studied.

2. The economic and engineering feasibility of debris basins and riprap in Rose Creek, Cudahy Slough and Tecolote Creek should be investigated to provide for cleaner run-off; if not feasible, plans should be made to overdredge at stream locations to retard deltaic growth which becomes unpleasant for swimmers and hazardous to boat operations.

3. Dredge as much area of the Bay as early in the development as possible. This was to reduce the turbidity and improve water odor, eliminate maintenance of channels dredged in silt and clay and relieve congestion in existing water areas.

4. From a viewpoint of water cleanliness, swimming beaches should be developed in the west part of the Bay in preference to the east part.

5. Consider all possibilities for constructing a wide beach strip and parking area for public use along the east side of Crown Point from the Causeway Bridge to the marsh area.

6. Do not permit industrial wastes or sewage to be disposed directly into the Bay, regardless of treatment. Provide and enforce rigorous requirements for use of shore disposal facilities by all boats using the Bay.

Harbor Surging

1. It was recommended that vertical walls not be constructed completely around Quivira Basin. One-fourth to one-half of its periphery should be sand or gravel beach or riprap placed on about 1:4 slope to minimize wave reflection and concentration of energy in the basin.

2. To decrease likely prohibitive surging in the proposed Glenn Rick Bay either (a) Make it 30% to 40% shoaler than the proposed Mission harbor turning basin, or (b) Make it 10% more narrow and the turning basin 10% wider than shown on the 1956 Master Plan.

3. Wharves should be of the floating type. Adequate "working" room should be allowed for vessels to have slack in mooring lines if fixed platforms are used.

Marine Life

1. A larger refuge than that shown on the 1956 Master Plan is recommended, if it is desired to preserve a favorable overall habitat for all marine life in Mission Bay.

2. In order to avoid unfavorable change in the marsh habitat of the study area in the University of California property, it was suggested that the proposed Fortuna Point not be constructed.

3. Generally adhere to the planned dredge depth of minus eight feet MLLW so as to maintain the favorable habitat for fish life now found in the Bay (greater depths would have adverse effects).

4. Introduce no new plant or animal species and avoid use of insecticides harmful to marine life.

5. To accomplish eel grass control on lower beach slopes, it was recommended that it be done by cutting or by other means of physical removal in June.

6. Eel grass control was to be limited to swimming areas. Extension of control into channels or open aquatic areas would harm the habitat for marine life.

Mission Bay has remained essentially uncontaminated in the years since these guidelines were proposed. Records of the Public Health Department, San Diego County, show that waters in Mission Bay have met standards set forth by the State each year since 1957. The standard is that the coliform count shall not exceed 10 MPN/ml in 20 percent of the number of samples taken. In each case where the standard has been exceeded, the source of contamination has been traced to sewer lift station near the Bay or to storm drains in the area. Minor bacterial counts below the acceptable level which have warranted investigation have also been traced to these sources.

San Diego County takes samples at four to six stations in Mission Bay during each spring before the swimming season in order to determine the bacterial count. In some years, this has been done in cooperative studies with the State of California

SUMMARY

Since the time Spanish influence was first felt in this region, the concept of land use in the area affected by sedimentation has changed with the needs of the community. The principal role of San Diego Bay has grown from that of a safe anchorage in the 16th century to its present one as a major seaport and center for a wide variety of maritime industries, while Mission Bay has evolved since World War II from a marshland to one of the major aquatic recreational parks in the country.

The sediment problem which was dealt with during the development of both bays originated in the natural sedimentary cycle in the San Diego River basin. The problem was recognized at two stages in the development of the community. The sediment threat in San Diego Bay became apparent in the 1850's because the river was emptying directly into the harbor area. It was recognized one hundred years later that the same sediment supply would deprive the community of a natural site for an aquatic recreation park in Mission Bay.

The source of sediment is primarily the San Diego River drainage area. Local and oceanic sediment sources of minor importance are also recognized. The magnitude of sediment influx in the delta area has been estimated empirically to be in the range 500, 000 to 700, 000 cubic yards per year. No specific sediment studies of the San Diego River basin have been made, but it is evident that flooding was the cause of sediment deposition in the estuarine system.

The effects of sediments in the system can only be postulated because this problem has been eliminated for all practical purposes. The physical or hydraulic structure of San Diego Bay was clearly being changed by the river delta growing into the harbor channel. Shallow Mission Bay was being filled by natural deltaic sedimentation when it was isolated from the sediment source. The ecological changes in the system have not been documented.

The quantity of sediment influx in the bay areas was not particularly large, but the site of deposition was confined in a small area near the harbor channel in San Diego Bay. The same situation existed later in Mission Bay once the river was diverted to that side of the delta. This Bay was so shallow that an annual influx of 500, 000 cubic yards of sediment created a serious problem. If the land or water areas were to be used for any purpose, this situation had to be corrected.

The relationship of quantity of sediment to the loss of beneficial use in either segment of the system is a subjective issue. For all practical purposes, the average annual influx of sediment to both bays can be treated as equal. The beneficial uses in both cases have continued to grow since sediment control was accomplished.

The potential benefits to be derived from sediment control in Mission Bay were recognized by the community after World War II. The affluence of the community, derived largely as a result of saving San Diego Harbor one hundred years earlier, was a key factor in initiating the development of a major aquatic park.

Public action and general support in the community were integral parts of the efforts taken to prevent loss of a useful harbor and to make the park possible. The first control effort culminated in the completion of a dike in 1877 which isolated San Diego River from the Harbor. The second control effort, completed in 1959, isolated the San Diego River from Mission Bay. An indication of the success of these efforts is reflected in the fact that more than thirty million dollars in private capital have been invested in Mission Bay, and that the annual dollar volume of industries directly involved with the marine environment in San Diego is in excess of two billion dollars.

APPENDIX I

Included here is a list of published government documents pertinent to the development of San Diego Harbor, California. U. S. Army Engineer District, Los Angeles. Corps of Engineers. April 1, 1967